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RESPIRATORY CARE

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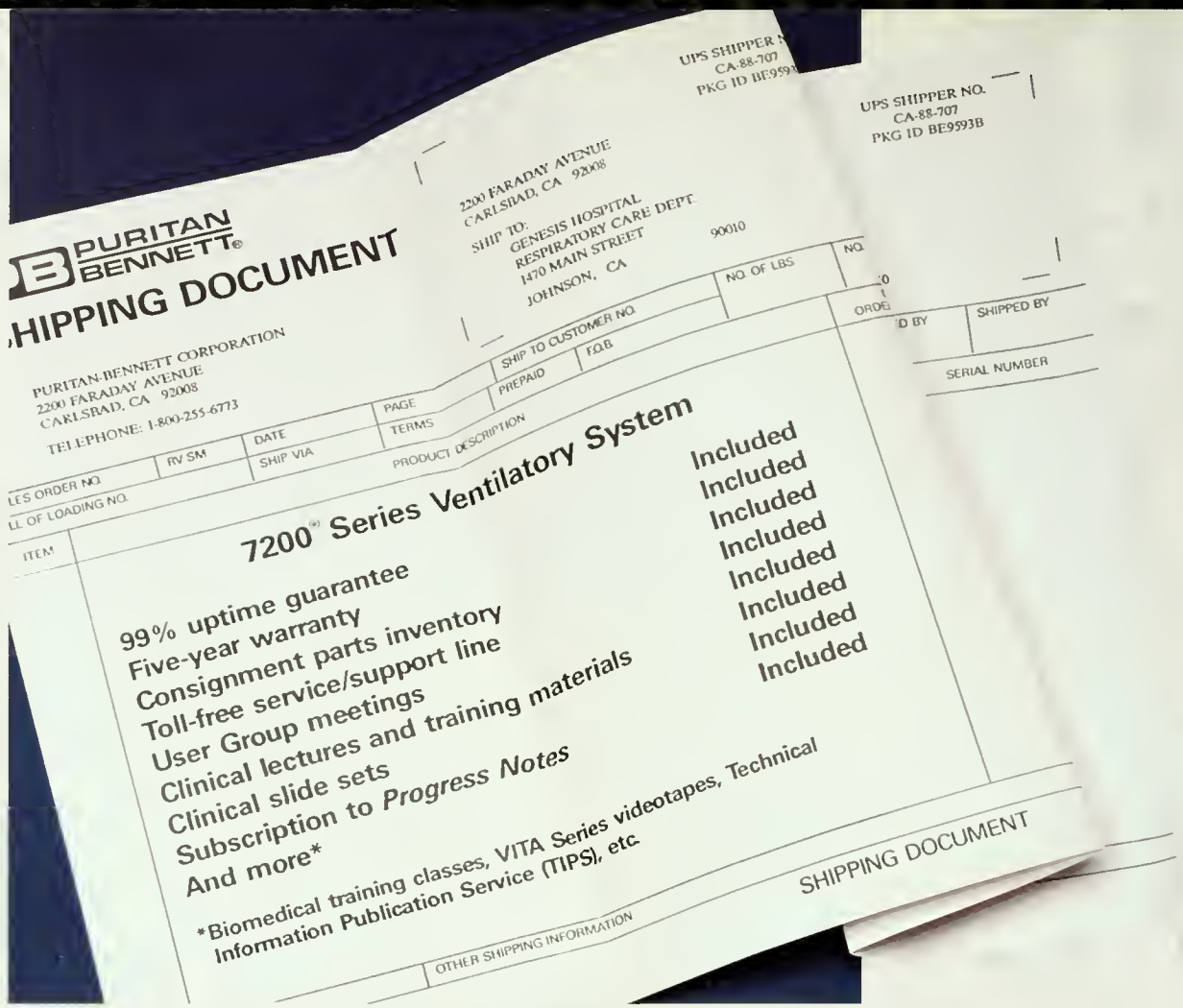
1992 OPEN FORUM Abstracts

- Comparison of Nebulizer Delivery Methods through a Neonatal Endotracheal Tube: A Bench Study
- HFV: Comparison of an Electronic Flow Interrupter and a New Pneumatic Oscillator
- Effects of Lithium Heparin Concentration on Whole Blood Analytes Measured on a Multichannel Blood Gas/Electrolyte System
- Bronchoscope Damage and Repair Costs: Results of a Regional Postal Survey
- Evaluation of a Directional-Tip Suction Catheter
- Solutions to "Murder Mystery" for Student Practice of Pulmonary Physiology Calculations



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ACCP. Report of Task Force on Research and Education for the Prevention and Control of Respiratory Diseases. Chest 1992;102(3,Suppl):1S-301S.

Diagnostic Critieria for Obstructive Sleep Apnea Syndrome in Children (editorial)—JL Carroll, GM Loughlin. Pediatr Pulmonol 1992;14:71.

Liquid Ventilation (state of the art review)—TH Shaffer, MR Wolfson, LC Clark Jr. Pediatr Pulmonol 1992;14:102.

Response to Inhaled Bronchodilators and Nonspecific Airway Hyperreactivity in Children with Cystic Fibrosis—I Sanchez, RE Powell, V Chernick. Pediatr Pulmonol 1992; 14:52.

We tested the hypothesis that children with CF who have a significant response to bronchodilator (BD) would respond positively to standard methacholine (Mch) challenge. Our objective was to correlate the response to BD with the concentration that produced a 20% fall (PC_{20}) in forced expiratory volume in 1 second (FEV_1). We studied 22 patients (12 males), aged 10.5 ± 0.7 years (mean ± SE), with a Shwachman-Kulczycki score 82 ± 2.6 and baseline FEV_1 of 80 ± 4.5 % predicted. Baseline expiratory flows, static lung volumes, and airway resistance were measured before and 30 min after inhaled salbutamol. On a separate day, within 2 weeks, a Mch challenge was given, with doubling concentrations from 0.03 to 8.0 mg/mL. A positive challenge was defined as a $PC_{20} \leq 2.0$ mg/mL, and a positive response to BD as a > 6% of FEV_1 increase. Mch challenge yielded 17 responders (R) with a PC_{20} of 0.5 ± 0.1 mg/mL, and 5 nonresponders (NR) with a PC_{20} of 8.8 ± 2.9 mg/mL. Baseline FEV_1 was 77 ± 5.3 % predicted in R compared to 89 ± 6.3% in NR ($p = < 0.001$). History of springtime rhinitis was positive in 9/17 R and 2/5 NR. No significant correlation was found between baseline FEV_1 and PC_{20}, or between change in FEV_1 post-BD and PC_{20}. A > 6% increase in FEV_1 was seen in 14/17 R (83% sensitivity) and in none of the 5 NR (100% specificity). In R, 8/17 patients had baseline FEV_1 < 80% predicted, compared to 1/5 in NR. We conclude that a change in FEV_1 > 6% from baseline after bronchodilator in children with CF suggests nonspecific airway hyperreactivity.

Spirometric and Endoscopic Evaluation of Airway Collapse in Infants with Bronchopulmonary Dysplasia—KS McCoy, CE Bagwell, M Wagner, J Sallent, M O'Keefe, PC Kosch. Pediatr Pulmonol 1992;14:23.

We evaluated 8 infants with bronchopulmonary dysplasia (BPD) at ages from 2-13 months who had repeated episodes of clinical respiratory deterioration associated with agitation. These episodes limited further weaning from ventilation or necessitated recurrent intubation and reinstitution of ventilation. All infants underwent spirometric evaluation and 6 also had endoscopic examination during simulated agitation episodes (elicited by toe pinching). All babies were found to have a very prolonged near zero expiratory airflow pattern, accompanied by vigorous diaphragmatic and abdominal muscle activity and rapid development of hypoxia. Six patients had endoscopically documented tracheal collapse under the same simulated circumstances. The episodes ceased with calming or sedation of the infants.

Hospital Outbreak of Multidrug-Resistant *Mycobacterium tuberculosis* Infections: Factors in Transmission to Staff and HIV-Infected Patients—C Beck-Sague, SW Dooley, MD Hutton, J Otten, A Breeden, JT Crawford, et al. JAMA 1992; 268:1280.

OBJECTIVE: To describe transmission of multidrug-resistant (MDR) *Mycobacterium tuberculosis* infec-

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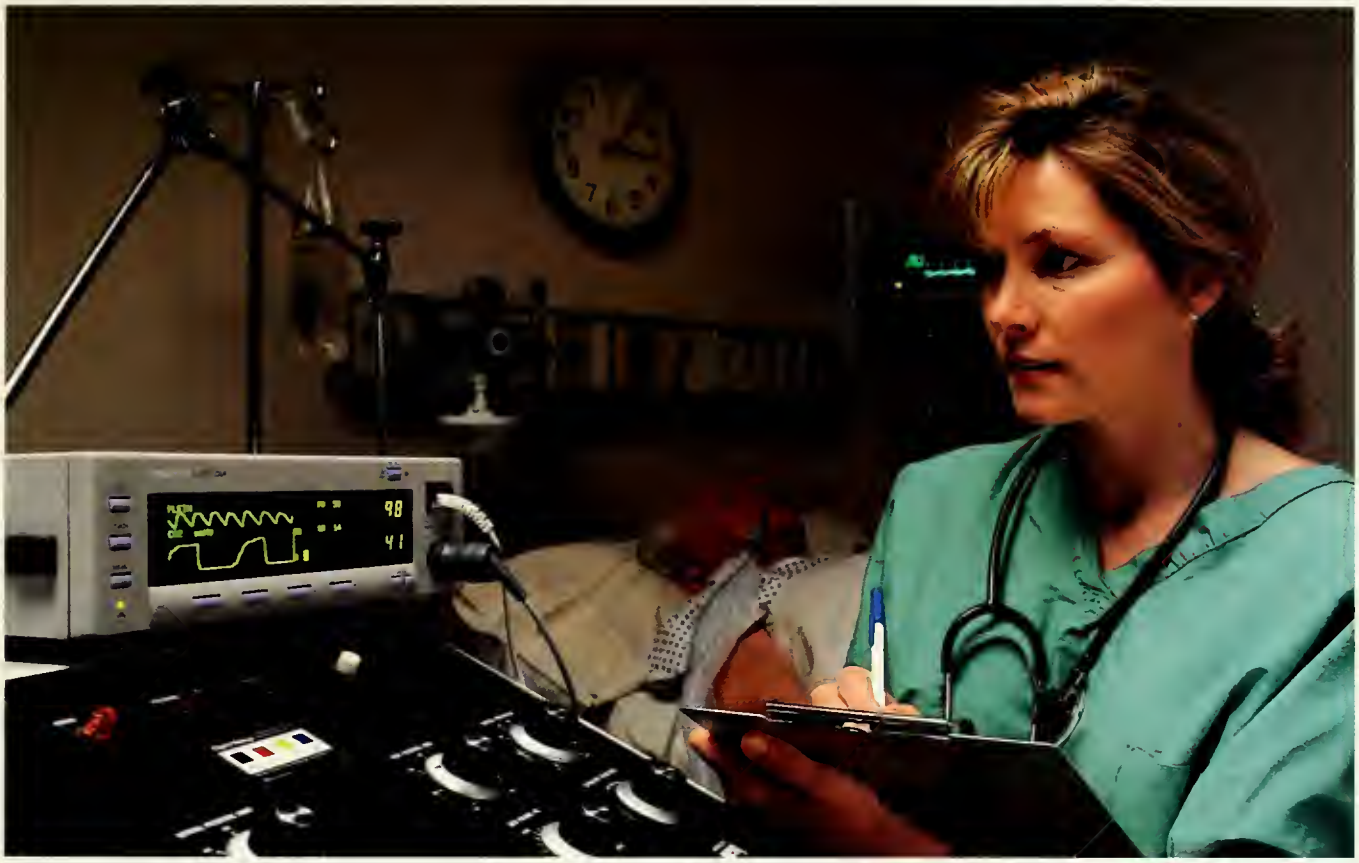

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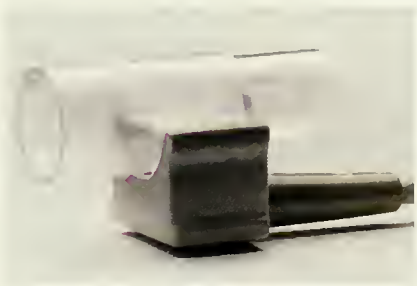

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tion among patients and health care workers (HCWs) in a ward and clinic for human immunodeficiency virus (HIV)-infected patients in a hospital, four studies were conducted. METHODS: Case patients and control patients were persons who had been treated in the HIV ward or clinic, whose clinical course was consistent with tuberculosis and who had at least one positive culture for *M tuberculosis* between January 1, 1988, and January 31, 1990, resistant to at least isoniazid and rifampin (case patients), or whose isolates were susceptible to all drugs tested (control patients). In the first study, case patients and control patients were compared to identify risk factors for MDR tuberculosis. In the second study, inpatient and outpatient days of MDR tuberculosis case patients were compared to determine whether acid-fast bacillus (AFB) smear-positivity or aerosolized pentamidine use was associated with higher numbers of subsequent MDR tuberculosis cases among exposed patients. In the third study, restriction fragment length polymorphism analysis was performed on available MDR and sensitive *M tuberculosis* isolates. In the fourth study, skin test conversion rates among HCWs in the HIV ward and clinic were compared with those of HCWs in another ward, and the strength of the associations between skin test conversions among HCWs on the HIV ward and the number of person-days that AFB smear-positive case patients and control patients were on this ward was estimated. RESULTS: Case patients were more likely than control patients to have been exposed on the HIV ward or clinic to an AFB smear-positive case patient ($p < 0.001$). Inpatient and outpatient days of MDR tuberculosis case patients were associated with more subsequent cases of MDR tuberculosis if exposing case patients were smear-positive or if they received aerosolized pentamidine ($p \leq 0.01$). Of 13 MDR isolates, all had one of two restriction fragment length polymorphism patterns; 10 sensitive isolates had restriction fragment length polymorphism patterns that were different from each other. The HCW skin test conversion rate was higher on the HIV ward and clinic than on the comparison ward ($p < 0.01$). The risk of occupational acquisition of infection increased in direct proportion to the number of person-days that AFB smear-positive case patients were on the HIV ward ($r = 0.75$; $p = 0.005$), but did not increase in proportion to the number of person-days that AFB smear-positive control patients were there ($r = -0.36$; $p = NS$). After isolation measures for AFB smear-positive tuberculosis patients were improved, MDR tuberculosis cases decreased to 7 of 214 tuberculosis patients. CONCLUSIONS: Nosocomial transmission of MDR *M tuberculosis* infection to patients and HCWs occurred on the HIV ward and clinic. Infectiousness of MDR tuberculosis case patients was associated with AFB sputum-smear positivity. Case patients with MDR tuberculosis created a greater risk of skin test conversion for HCWs on the HIV ward than drug-susceptible control patients.

Cardiac Resuscitation with Percutaneous Cardiopulmonary Support—MR Rees, T Browne, UM Sivananthan, S Whittaker, D Hick, SP Verma, et al. Lancet 1992;340:513.

Percutaneous cardiopulmonary support (CPS) was initiated in 9 patients to provide haemodynamic stability after failure of conventional resuscitation. 4 patients were in cardiogenic shock and 4 remained in asystole, with 1 in resistant ventricular fibrillation, after cardiac arrest. During CPS for those in cardiogenic shock, the mean intra-arterial pressures ranged from 65-100 mm Hg (mean 84), at flowrates of between 3 to 5 L/min (mean 3.9). 2 patients underwent technically successful coronary angioplasty. No patient in this group survived. In the cardiac arrest group, acceptable mean intra-arterial blood pressures were achieved (mean 95, range 90-100 mm Hg) at flowrates of between 2 to 3 L/min (mean 2.6). All 5 subjects underwent technically successful coronary angioplasty whilst on CPS. 4 survived. 2 were alive and well at 12 months follow-up, 1 of whom had returned to work; the third is alive and well at 4 months.

Venous Air Embolism: Clinical and Experimental Considerations—SL Orebaugh. Crit Care Med 1992;20: 1169.

OBJECTIVE: To examine the existing literature concerning venous air embolism. Causes, pathophysiology, and management are emphasized. DATA SOURCES: The literature that was reviewed was retrieved from the Medline System under the headings "venous air embolism," "air embolism," "therapy of air embolism," "etiology of venous air embolism," and "pathophysiology of venous air embolism" for the years 1970 to 1991. A manual search, derived from the references of these papers, was performed to obtain relevant citations for the years preceding 1970. STUDY SELECTION: Experimental (animal) data, case reports, case series, and clinical investigations are included. CONCLUSIONS: Venous air embolism is an infrequent complication of invasive diagnostic and therapeutic maneuvers. The cardiovascular, pulmonary, and central nervous systems may all be affected, with severity ranging from no symptoms to immediate cardiovascular collapse. Therapeutic interventions include mechanical measures, such as positioning, withdrawal of air from the right atrium, and measures aimed at

reducing bubble size. Hyperbaric oxygen therapy holds some promise in accomplishing the latter, but randomized, controlled trials demonstrating efficacy have yet to be performed.

Extracorporeal Life Support for Pediatric Respiratory Failure—FW Moler, JR Custer, RH Bartlett, J Palmisano, JN Meliones, RE Delius, et al. Crit Care Med 1992;20:1112.

OBJECTIVES: The purposes of this report are to (a) describe the University of Michigan experience with venoarterial or venovenous extracorporeal life support for severe pediatric pulmonary rescue therapy, and (b) examine survivors and nonsurvivors for differences that might be useful for examination in future, prospective studies. DESIGN: Case series report. Phase I study of safety and effectiveness of extracorporeal life support for pediatric respiratory failure. SETTING: University of Michigan Medical Center. PATIENTS: Non-neonatal pediatric patients treated with extracorporeal life support for severe respiratory failure at the University of Michigan. INTERVENTIONS: Extracorporeal life support for pulmonary failure. MEASUREMENTS & MAIN RESULTS: From November 1982 until May 1991, 25 pediatric patients underwent extracorporeal life support for severe pulmonary failure. Twenty patients were treated in the last 36 months. Sixty percent (15/25 patients) survived their life-threatening respiratory illness, were weaned from mechanical ventilation, and were discharged home. The mean patient age was 4.1 yrs, and mechanical ventilation duration before extracorporeal life support was 5.9 days. Mean blood gas data and mechanical ventilation pressures before extracorporeal life support were peak inspiratory pressure of 48.6 cm H_2O, mean airway pressure of 21.9 cm H_2O, positive end-

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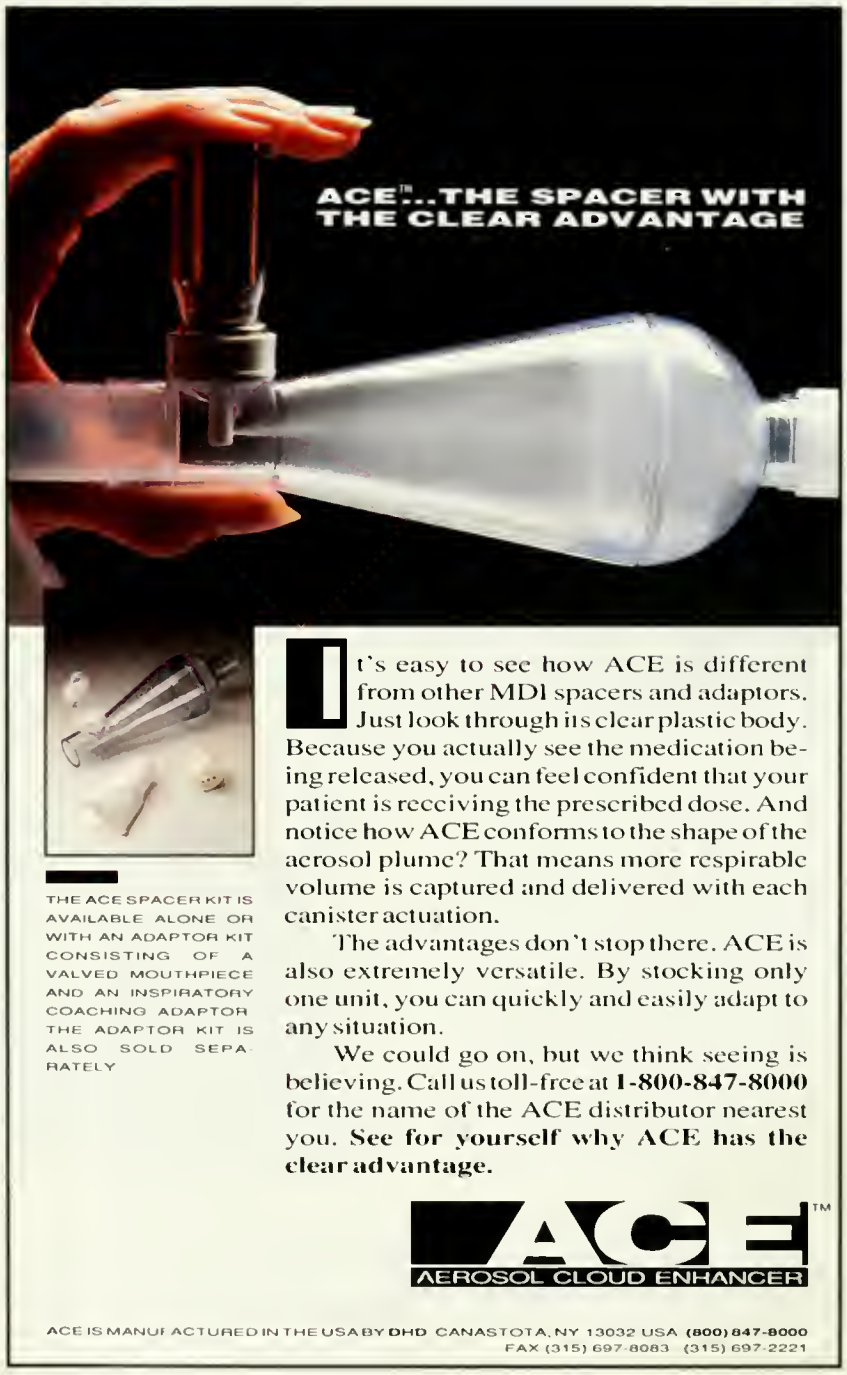
expiratory pressure of 9.7 cm H_2O, P_{aCO_2} of 43 torr (5.7 kPa), P_{aO_2} of 69 torr (9.1 kPa), estimated alveolar-arterial oxygen gradient of 563 torr (75 kPa), and F_{IO_2} of 0.98. Variables associated with survival included age of survivors vs nonsurvivors, 2.1 vs 7.1 yrs ($p < 0.02$); peak inspiratory pressure of survivors vs nonsurvivors, 43.1 vs 57.9 cm H_2O ($p < 0.03$); mean airway pressure of survivors vs nonsurvivors, 18.4 vs 27.2 cm H_2O ($p < 0.03$); and positive end-expiratory pressure of survivors vs nonsurvivors, 8.1 vs 12.1 cm H_2O ($p < 0.01$). There were no differences detectable in the blood gas values (P_{aO_2}, P_{aCO_2}, $P_{[A\text{-}a]O_2}$) in survivors and nonsurvivors before extracorporeal life support. The number of days mechanical ventilation was used before extracorporeal life support in survivors and in nonsurvivors was similar. CONCLUSION: Extracorporeal life support is an effective rescue therapy for pediatric patients with severe respiratory failure (University of Michigan survival rate of 60%).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Validation of Respiratory Mechanics Software in Microprocessor-Controlled Ventilators—RJ Korst, R Orlando III, NS Yeston, M Molin, AC De Graff Jr, E Gluck. Crit Care Med 1992:20:1152.

BACKGROUND & METHODS: Several microprocessor-controlled ventilators, available for clinical use, contain optional computer software programs capable of performing near-instantaneous determinations of airway resistance and lung compliance. This study was undertaken to determine the validity of the measurements for airway resistance and lung compliance obtained by the software packages on three microprocessor-controlled ventilators. Three ventilator models were studied. An artificial ventilator-patient circuit was constructed using a test lung and an endotracheal tube. Airway pressure and gas flow curves were recorded using a test lung and an endotracheal tube. Airway pressure and gas flow curves were recorded using conventional means. Static lung compliance and airway resistance were calculated using standard equations, while automated measurements were obtained from the ventilators. The following parameters were then varied

to simulate a wide variety of clinical situations: tidal volume, peak inspiratory flowrate, respiratory rate, endotracheal tube, and test lung compliance. RESULTS: Automated measurements were highly correlated with values obtained manually (resistance: Puritan-Bennett 7200a r^2 = 0.94, Bear 5 r^2 = 0.98, Veolar r^2 = 0.96; compliance: 7200a r^2 = 0.93, Bear 5 r^2 = 0.97, Veolar r^2 = 0.97). Calculated limits of agreement between the two methods demonstrate that although not in absolute agreement, the software-determined values for airway resistance and lung compliance differed fro the manually derived values in a ventilator-specific, predictable fashion. CONCLUSIONS: The correlation and agreement demonstrated between values of airway resistance and lung compliance measured by the respiratory mechanics software packages and those values derived manually suggest that these software packages and be useful for measuring trends, as well as responding to treatment in the clinical setting. These results apply only to the controlled, mechanical ventilation mode. Further studies are indicated to validate this software in patients capable of generating spontaneous breaths.

Cost Reduction in Diagnosing *Pneumocystis carinii* Pneumonia: Sputum Induction versus Bronchoalveolar Lavage as the Initial Diagnostic Procedure—RW Glenny, DJ Pierson. Am Rev Respir Dis 1992;145:1425.

Sputum induction (SI) is a sensitive and specific method for diagnosing *Pneumocystis carinii* pneumonia (PCP) in patients with AIDS. Although less expensive than bronchoscopy with bronchoalveolar lavage (BAL), SI followed by BAL does not necessarily reduce costs compared with BAL alone. Cost analysis demonstrates that the cost of diagnosing PCP is dependent on the prevalence of PCP ($PCP_{prevalence}$) in the studied population, the sensitivity of SI ($SI_{sensitivity}$) for diagnosing PCP, and the relative costs of SI and BAL (SI_{cost} and BAL_{cost}) for diagnosing PCP. In any given clinical setting, SI reduces the cost of diagnosing PCP if $(PCP_{prevalence})(SI_{sensitivity}) > SI_{cost}/BAL_{cost}$. A graphic approach relating these parameters is also presented. Evaluation of reported $PCP_{prevalence}$ and $SI_{sensitivity}$ from recent literature illustrates that SI is not always the least costly method for diagnosing PCP. Cost reduction is not the only measure of a diagnostic procedure's value, and other aspects (such as discomfort, availability, risks, and patient prognosis) must be considered. The cost analysis approach used in this study identifies those variables that can be manipulated to reduce the cost of diagnosing PCP.

A Self-Complete Measure of Health Status for Chronic Airflow Limitation: The St George's Respiratory Questionnaire—PW Jones, FH Quirk, CM Baveystock, P Littlejohns. Am Rev Respir Dis 1992; 145:1321.

A need was identified for a fixed-format self-complete questionnaire for measuring health in chronic airflow limitation. A 76-item questionnaire was developed, the St George's Respiratory Questionnaire (SGRQ). Three component scores were calculated: symptoms, activity, and impacts (on daily life), and a total score. Three studies were performed. (1) Repeatability was tested over 2 wk in 40 stable asthmatic patients and 20 patients with stable COPD. The coefficient of variation for the SGRQ total score was 19%. (2) SGRQ scores were compared with spirometry, 6-min walking distance (6-MWD), Medical Research Council respiratory symptoms questionnaire, anxiety, depression, and general health measured using the Sickness Impact Profile score. A total of 141 patients were studied, mean age 63 yr (range 31-75) and prebronchodilator FEV_1 47% (range 11-114%). SGRQ scores correlated with appropriate comparison measures. For example, symptom score versus frequency of wheeze, r^2 = 0.32, $p < 0.0001$; activity versus 6-MWD, $r^2 = 0.50$, $p < 0.0001$; impact versus anxiety, $r^2 = 0.38$, $p < 0.0001$. Multivariate analysis demonstrated that SGRQ scores summed a number of areas of disease activity. (3) Changes in SGRQ scores and other measures were studied over 1 yr in 133 patients. Significant correlations were found between changes in SGRQ scores and the comparison measures (minimum $r^2 > 0.05$, $p < 0.01$). Multivariate analysis showed that change in total SGRQ score summed changes in a number of aspects of disease activity. We conclude that the SGRQ is a valid measure of impaired health in diseases of chronic airflow limitation that is repeatable and sensitive.

A Model of Airway Narrowing in Asthma and in Chronic Obstructive Pulmonary Disease—BR Wiggs, C Bosken, PD Paré, A James, JC Hogg. Am Rev Respir Dis 1992; 145:1251.

We have examined the effect of airway wall thickening, loss of lung recoil, and airway smooth muscle shortening on the increase in airway resistance using a model of the human tracheobronchial tree. The values for airway wall thickening were determined morphometrically on the postmortem or surgically resected lungs of normal subjects, patients with moderate chronic obstructive pulmonary disease, and patients with severe asthma. Loss of recoil was stimulated by deflating airways along their pressure-area curves by 1-3 cm H_2O. Values of smooth mus-

cle shortening between 20 and 40% were used in the model to generate sigmoidal-shaped "dose-response" curves. The analysis shows that moderate amounts of airway wall thickening, which have little effect on baseline resistance, can profoundly affect the airway narrowing caused by smooth muscle shortening—especially if the wall thickening is localized in peripheral airways. The combination of a loss of recoil and airway wall thickening are more than additive in their effect on simulated airway responsiveness. We conclude that airway wall thickening and a loss of lung recoil can partially explain the airway hyperresponsiveness observed in patients with chronic obstructive lung disease and asthma.

Improved Outcome Based on Fluid Management in Critically Ill Patients Requiring Pulmonary Artery Catheterization—JP Mitchell, D Schuller, FS Calandrino, DP Schuster. Am Rev Respir Dis 1992; 145:990.

We performed a randomized, prospective trial to evaluate whether fluid management that emphasized diuresis and fluid restriction in patients with pulmonary edema could affect the development or resolution of extravascular lung water (EVLW), as well as time on mechanical ventilation and time in the intensive care unit (ICU), in critically ill patients requiring pulmonary artery catheterization (PAC). PAC was performed on 101 patients. A total of 52 patients were randomized to an EVLW management group using a protocol based on bedside indicator-dilution measurements of EVLW. The other 49 patients were randomized to a wedge pressure (WP) management group in whom fluid management decisions were guided by WP measurements. A total of 89 patients had pulmonary edema (defined as EVLW > 7 mL/kg ideal body weight). Except for a clinically unimportant difference in mean age, the two groups were entirely comparable at baseline. The study groups were managed differently, as evidenced by cumulative input-output of 2,239 ± 3,695 mL (median = 1,600 mL) in the WP group versus 142 ± 3,632 mL (median = 754 mL) in the EVLW group ($p = 0.001$). EVLW decreased significantly, and ventilator-days and ICU days were significantly shorter

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only in patients from the EVLW group. No clinically significant adverse effect occurred as a result of following the EVLW group algorithm. Thus, a lower positive fluid balance, especially in patients with pulmonary edema regardless of cause, is associated with reduced EVLW, ventilator-days, and ICU days.

The Effect of Maternal Smoking during Pregnancy on Early Infant Lung Function—JP Hanrahan, IB Tager, MR Segal, TD Tosteson, RG Castile, H Van Vunakis, ST Weiss, FE Speizer. Am Rev Respir Dis 1992;145:1129.

We studied the effect of prenatal maternal cigarette smoking on the pulmonary function (PF) of 80 healthy infants tested shortly after birth (mean 4.2 ± 1.9 wk). Mothers' prenatal smoking was measured by (1) questionnaire reports at each prenatal visit of the number of cigarettes smoked per day, and (2) urine cotinine concentrations (corrected for creatinine) obtained at each visit. Infant PF was assessed by partial expiratory flow-volume curves and helium-dilution measurement of FRC. Forced expiratory flowrates were significantly lower in infants born to smoking mothers, both when unadjusted and after controlling for infant size, age, sex, and passive exposure to environmental tobacco smoke (ETS) between birth and the time of PF testing. Flow at functional residual capacity ($\dot{V}_{FRC}$) in infants born to smoking mothers was lower than that found in infants whose mothers did not smoke during pregnancy (74.3 ± 15.9 vs 150.4 ± 8.9 mL/s; p = 0.0007). Differences remained significant when flow was corrected for lung size ($\dot{V}_{FRC}$/FRC: 0.87 ± 0.26 vs 1.77 ± 0.12 s^{-1}; p = 0.013). No differences in pulmonary function were evident among infants exposed and unexposed to ETS in the home after stratifying by prenatal exposure status. We conclude that maternal smoking during pregnancy is associated with significant reductions in forced expiratory flowrates in young infants. The results suggest that maternal smoking during pregnancy may impair in utero airway development and/or alter lung elastic properties. We speculate that these effects of maternal prenatal smoking on early levels of forced expiratory flow may be an important factor predisposing infants to the oc-

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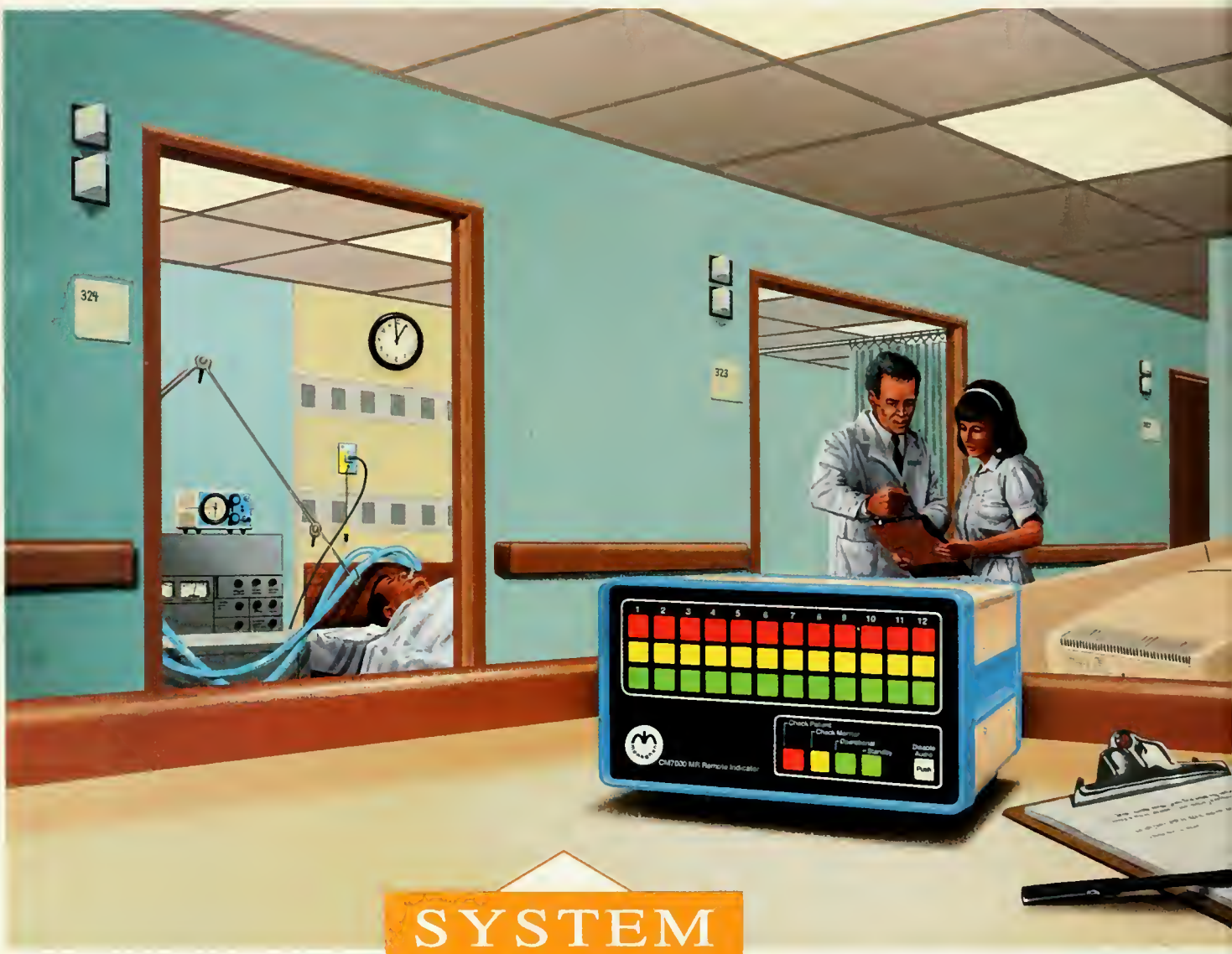

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currence of wheezing illness later in childhood.

Nebulizer Function during Mechanical Ventilation—TG O'Riordan, MJ Greco, RJ Perry, GC Smaldone. Am Rev Respir Dis 1992;145: 1117.

In the setting of mechanical ventilation, recent studies have cast doubt on the ability of nebulizer systems to deliver adequate amounts of medication. We therefore studied ventilator-related and nebulizer-related factors that could potentially affect the amount of aerosol inhaled by an intubated subject. Utilizing two separate protocols, we used a bench model of a ventilator circuit, radiolabeled (technetium pertechnetate, ^{99m}Tc) saline droplets and a filter technique to measure the percentage of radioaerosol delivered. First, we compared four commercially available jet nebulizers and found that there were significant differences in rate of aerosol production between systems, ranging from 3-37%. Delivered aerosol was measured at different ventilator settings, and it was found that the duty cycle can potentially influence output by sevenfold. Some nebulizers were also sensitive to changes in the initial volume of solution placed in the nebulizer. The inclusion of a humidification device significantly reduced output by a mean of 41 ± 3.5%, but it did not affect particle distribution. Endotracheal tube diameter was not an important variable. Then, with the effects of the above variables established, a separate series of experiments was performed to test whether the use of different radiolabeling compounds can confound the measurement of inhaled drugs. Two nebulizers (AeroTech II and Twin Jet) and pentamidine as the test drug were studied with fixed ventilator settings, treatment time, endotracheal tube size, and volume fill. No humidification was used. The nebulizer solution was labeled with ^{99m}Tc, which was bound to either human serum albumin (HSA) or sulfur colloid (SC). To assess the accuracy and precision of these radioisotopes as indices of drug delivery, we sampled aerosol particles from the inspiratory line using a cascade impactor. Each stage of the cascade was analyzed for drug activity (using high performance liquid chromatography) in nanograms and radioactivity in microcuries. The quantities of drug and radioactivity captured in the aerosol were expressed as percentages of the initial amounts placed in the nebulizer. Using linear regression analysis, there was a close correlation between the radiation inhaled and the pentamidine inhaled for both radioaerosols. However, the slope of the regression line for HSA followed a line of identity, whereas for SC the slope was 0.339. This indicates that if the nebulizer output of drug and radiolabel were assumed to be equivalent, as in most previous studies, the use of SC would underestimate drug inhaled by a factor of 3:1. Similar findings occurred with both nebulizers. We conclude that nebulized aerosol delivery during mechanical ventilation is influenced by the type of nebulizer, the treatment time, the duty cycle, the volume fill of the nebulizer, and the presence of a humidification device. In addition, measurement of drug delivery can be grossly underestimated depending on the choice of radiolabel. If these factors are defined, however, nebulizer systems can be highly efficient in delivering medication to intubated, mechanically ventilated subjects.

A Double-Blind Trial of Nocturnal Supplemental Oxygen for Sleep Desaturation in Patients with Chronic Obstructive Pulmonary Disease and a Daytime P_{aO_2} above 60 mm Hg—EC Fletcher, RA Luckett, S Goodnight-White, CC Miller, W Qian, C Costarangos-Galarza. Am Rev Respir Dis 1992;145:1070.

The efficacy of nasal oxygen during sleep was evaluated in patients with COPD, episodic rapid eye movement sleep desaturation, and a daytime $P_{aO_2} > 60$ mm Hg. The double-blind, randomized 3-yr trial used nasal oxygen versus room air in two groups of nocturnal sleep desaturating subjects. The setting was the outpatient chest clinic of a Veterans Affairs Medical Center. There were 51 patients with moderate to severe COPD, daytime $P_{aO_2} \geq 60$ torr: 38 with proven REM sleep desaturation and 13 without desaturation. Nocturnal oxygen at 3 L/min was delivered by concentrator to 19 desaturating subjects, and room air at 3 L/min was delivered by defective concentrator to the remaining 19 desaturating subjects. There was no gas therapy for the 13 nondesaturating subjects. The nocturnal desaturator group who received supplemental oxygen during sleep over 36 months showed a significant downward trend in pulmonary artery pressure (–3.7 torr) compared with desaturating patients treated with room air (+3.9 torr). Nonvascular parameters of hypoxia, such as hemoglobin and red blood cell mass, did not differ between the sham- and oxygen-treated groups. Mortality was decidedly higher in the desaturating patients compared with nondesaturating subjects, but there was no significant difference between oxygen- and sham-treated desaturating subjects. We conclude that nasal supplemental oxygen used during sleep to reverse episodic desaturation in COPD patients whose daytime P_{aO_2} is above 60 torr has a beneficial effect in reducing pulmonary artery pressure. Further study is needed to examine the usefulness of supplemental oxygen in reducing mortality in COPD patients with nocturnal desaturation who do not qualify for home oxygen by current criteria.

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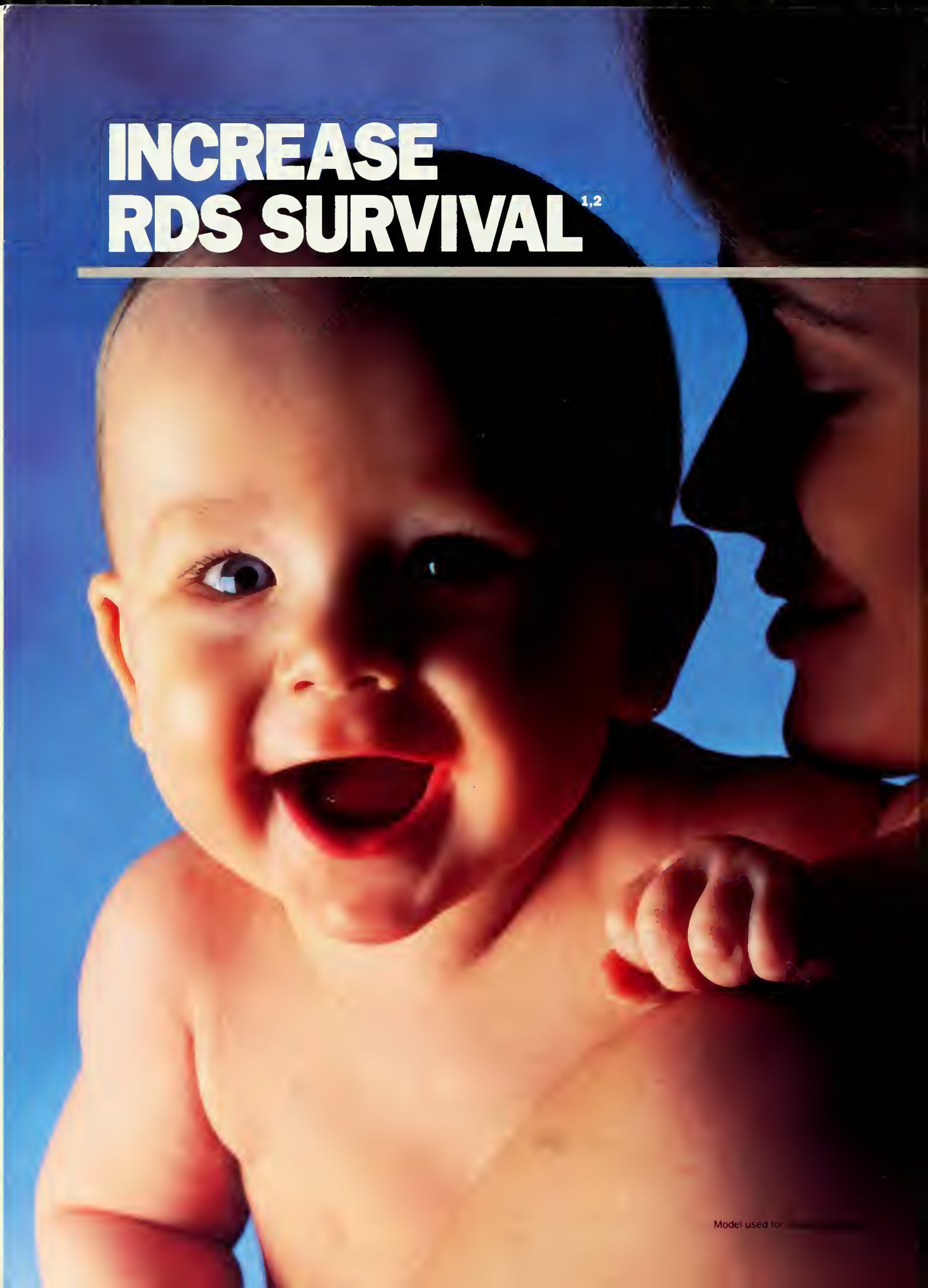
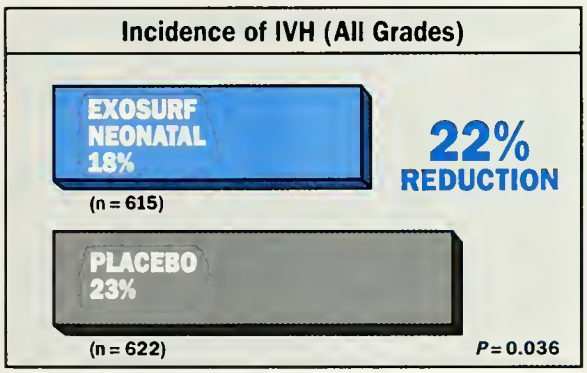


Model used for

REDUCE THE RISK OF CEREBRAL HEMORRHAGE

Significant IVH Reduction in Infants ≥1250 g

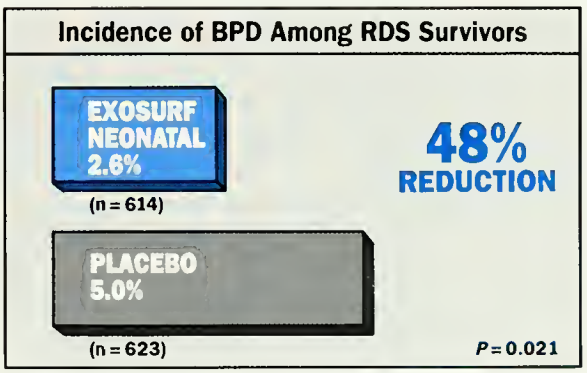
Despite successes in improving the survival of infants with RDS, intraventricular hemorrhage (IVH) remains a serious problem.[3-5] However, in a recently reported placebo-controlled rescue trial in infants ≥1250 g, EXOSURF Neonatal actually *reduced* the incidence of IVH.[2] In trials of smaller infants (<1250 g), EXOSURF Neonatal has never been observed to significantly increase IVH.



Two-dose treatment. Incidence of IVH in infants weighing 1250 g or more.
Adapted from Long et al[2 (p1700)]

Significant BPD Reduction in Infants ≥1250 g

In the rescue trial involving over 1200 infants, administration of EXOSURF Neonatal significantly reduced the incidence of bronchopulmonary dysplasia (BPD) by nearly 50% ($P = 0.021$).



Two-dose treatment. Incidence of BPD in 28-day survivors following RDS in infants weighing 1250 g or more.
Adapted from Long et al[2 (p1699)]

No Increase in Sepsis

No difference in the incidence of sepsis has been seen with EXOSURF Neonatal during placebo-controlled trials (n = 1517). The rate of sepsis was similar in an open trial of 11,455 infants.[6]

No Animal Proteins

EXOSURF is purely synthetic and carries no known infectious or immunologic risks.

Other Safety Considerations

Various forms of pulmonary air leak were reduced in all controlled trials. A single controlled study in infants 500-699 g reported a significant increase in pulmonary hemorrhage.[7] Significant increases in apnea were reported in three controlled trials.[1,2,8] Apnea appears to be a marker for improved survival.[2]

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*Increased pulmonary hemorrhage was noted in one trial of infants 500-699 g[7]; increased apnea has been noted in some trials.[1,2,8]

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*Increased pulmonary hemorrhage was noted in one trial of infants 500-699 g[7]; increased apnea has been noted in some trials.[1,2,8]

PLEASE CONSULT FULL PRODUCT INFORMATION BEFORE PRESCRIBING

INDICATIONS AND USAGE: Exosurf Neonatal is indicated for: 1. **Prophylactic** treatment of infants with birth weights of less than 1350 grams who are at risk of developing RDS (see PRECAUTIONS), 2. **Prophylactic** treatment of infants with birth weights greater than 1350 grams who have evidence of pulmonary immaturity, and 3. **Rescue** treatment of infants who have developed RDS.

CONTRAINDICATIONS: There are no known contraindications to treatment with Exosurf Neonatal.

WARNINGS: Intratracheal Administration Only: Exosurf Neonatal should be administered only by instillation into the trachea (see DOSAGE AND ADMINISTRATION). **General:** The use of Exosurf Neonatal requires expert clinical care by experienced neonatologists and other clinicians who are accomplished at neonatal intubation and ventilatory management. Adequate personnel, facilities, equipment, and medications are required to optimize perinatal outcome in premature infants. Vigilant clinical attention should be given to all infants prior to, during, and after administration of Exosurf Neonatal. **Acute Effects:** Exosurf Neonatal can rapidly affect oxygenation and lung compliance. **Lung Compliance:** If chest expansion improves substantially after dosing, peak ventilator inspiratory pressures should be reduced immediately, without waiting for confirmation of respiratory improvement by blood gas assessment. Failure to reduce inspiratory ventilator pressures rapidly in such instances can result in lung overdistention and fatal pulmonary air leak. **Hyperoxia:** If the infant becomes pink and transcutaneous oxygen saturation is in excess of 95%, FiO_2 should be reduced in small but repeated steps (until saturation is 90 to 95%) without waiting for confirmation of elevated arterial pO_2 by blood gas assessment. Failure to reduce FiO_2 in such instances can result in hyperoxia. **Hypocarbia:** If arterial or transcutaneous CO_2 measurements are <30 torr, the ventilator rate should be reduced at once. Failure to reduce ventilator rates in such instances can result in marked hypocarbia, which is known to reduce brain blood flow. **Pulmonary Hemorrhage:** In the single study conducted in infants weighing <700 grams at birth, the incidence of pulmonary hemorrhage (10% vs 2% in the placebo group) was significantly increased in the Exosurf Neonatal group. None of the five studies involving infants with birth weights >700 grams showed a significant increase in pulmonary hemorrhage in the Exosurf Neonatal group. In a cross-study analysis of these five studies, fatal pulmonary hemorrhage occurred in three infants, two in the Exosurf Neonatal group and one in the placebo group. Mortality from all causes among infants who developed pulmonary hemorrhage was 43% in the placebo group and 37% in the Exosurf Neonatal group. Pulmonary hemorrhage in both Exosurf Neonatal and placebo infants was more frequent in infants who were younger, smaller, male, or who had a patent ductus arteriosus. Pulmonary hemorrhage typically occurred in the first 2 days of life in both treatment groups. **Mucous Plugs:** Infants whose ventilation becomes markedly impaired during or shortly after dosing may have mucous plugging of the endotracheal tube, particularly if pulmonary secretions were prominent prior to drug administration. Suctioning of all infants prior to dosing may lessen the chance of mucous plugs obstructing the endotracheal tube. If endotracheal tube obstruction from such plugs is suspected, and suctioning is unsuccessful in removing the obstruction, the blocked endotracheal tube should be replaced immediately.

PRECAUTIONS: General: In the controlled clinical studies, infants known prenatally or postnatally to have major congenital anomalies, or who were suspected of having congenital infection, were excluded from entry. However, these disorders cannot be recognized early in life in all cases, and a few infants with these conditions were entered. The benefits of Exosurf Neonatal in the affected infants who received drug appeared to be similar to the benefits observed in infants without anomalies or occult infection. **Prophylactic Treatment—Infants <700 Grams:** In infants weighing 500 to 700 grams, a single prophylactic dose of Exosurf Neonatal significantly improved FiO_2 and ventilator settings, reduced pneumothorax, and reduced death from RDS, but increased pulmonary hemorrhage (see WARNINGS). Overall mortality did not differ significantly between the placebo and Exosurf Neonatal groups. Data on multiple doses in infants in this weight class are not yet available. **Rescue Treatment—Number of Doses:** A small number of infants with RDS have received more than two doses of Exosurf Neonatal as rescue treatment. Definitive data on the safety and efficacy of these additional doses are not available. **Carcinogenesis, Mutagenesis, Impairment of Fertility:** Exosurf Neonatal at concentrations up to 10,000 µg/plate was not mutagenic in the Ames Salmonella assay. Long-term studies have not been performed in animals to evaluate the carcinogenic potential of Exosurf Neonatal. The effects of Exosurf Neonatal on fertility have not been studied.

ADVERSE REACTIONS:
General: Premature birth is associated with a high incidence of morbidity and mortality. Despite significant reductions in overall mortality associated with Exosurf Neonatal, some infants who received Exosurf Neonatal developed severe complications and either survived with permanent handicaps or died. In controlled clinical studies evaluating the safety and efficacy of Exosurf Neonatal, numerous safety assessments were made. In infants receiving Exosurf Neonatal, pulmonary hemorrhage, apnea and use of methylxanthines were increased. A number of other adverse events were significantly reduced in the Exosurf Neonatal group, particularly various forms of pulmonary air leak and use of pancuronium. ***Reflux:*** Reflux of Exosurf Neonatal into the endotracheal tube during dosing has been observed and may be associated with rapid drug administration. If reflux occurs, drug administration should be halted and, if necessary, peak inspiratory pressure on the ventilator should be increased by 4 to 5 cm H_2O until the endotracheal tube clears. ***>20% Drop in Transcutaneous Oxygen Saturation:*** If transcutaneous oxygen saturation declines during dosing, drug administration should be halted and, if necessary, peak inspiratory pressure on the ventilator should be increased by 4 to 5 cm H_2O for 1 to 2 minutes. In addition, increases of FiO_2 may be required for 1 to 2 minutes.

DOSAGE AND ADMINISTRATION: Preparation of Suspension: Exosurf Neonatal is best reconstituted immediately before use because it does not contain antibacterial preservatives. However, the reconstituted suspension is chemically and physically stable when stored at 2° to 30°C (36° to 86°F) for up to 12 hours following reconstitution. Solutions containing buffers or preservatives should not be used for reconstitution. **Do Not Use Bacteriostatic Water for Injection, USP.** Each vial of Exosurf Neonatal should be reconstituted only with **8 mL** of the accompanying diluent (preservative-free Sterile Water for Injection). **Dosage: Accurate determination of weight at birth is the key to accurate dosing.** ***Prophylactic Treatment:*** The first dose of Exosurf Neonatal should be administered as a single 5 mL/kg dose as soon as possible after birth. Second and third doses should be administered approximately 12 and 24 hours later to all infants who remain on mechanical ventilation at those times. ***Rescue Treatment:*** Exosurf Neonatal should be administered in two 5 mL/kg doses. The initial dose should be administered as soon as possible after the diagnosis of RDS is confirmed. The second dose should be administered approximately 12 hours following the first dose, provided the infant remains on mechanical ventilation. **Use of Special Endotracheal Tube Adapter:** With each vial of Exosurf Neonatal for Intratracheal Suspension, five different sized endotracheal tube adapters each with a special right angle Luer®-lock sideport are supplied. The adapters are clean but not sterile. **Administration:** The infant should be suctioned prior to administration of Exosurf Neonatal. Exosurf Neonatal suspension is administered via the sideport on the special endotracheal tube adapter **WITHOUT INTERRUPTING MECHANICAL VENTILATION.** Each Exosurf Neonatal dose is administered in two 2.5 mL/kg half-doses. Each half-dose is instilled slowly over 1 to 2 minutes (30 to 50 mechanical breaths) in small bursts timed with inspiration. After the first 2.5 mL/kg half-dose is administered in the midline position, the infant's head and torso are turned 45° to the **right** for 30 seconds while mechanical ventilation is continued. After the infant is returned to the midline position, the second 2.5 mL/kg half-dose is given in an identical fashion over another 1 to 2 minutes. The infant's head and torso are then turned 45° to the **left** for 30 seconds while mechanical ventilation is continued, and the infant is then turned back to the midline position. These maneuvers allow gravity to assist in the distribution of Exosurf Neonatal in the lungs. During dosing, heart rate, color, chest expansion, facial expressions, the oximeter, and the endotracheal tube patency and position should be monitored. **Suctioning should not be performed for two hours after Exosurf Neonatal is administered, except when dictated by clinical necessity.**

HOW SUPPLIED: Exosurf Neonatal for Intratracheal Suspension is supplied in a carton containing one 10 mL vial of Exosurf Neonatal for Intratracheal Suspension, one 10 mL vial of Sterile Water for Injection, and five endotracheal tube adapters (2.5, 3.0, 3.5, 4.0, and 4.5 mm I.D.). (NDC 0081-0207-01). Store Exosurf Neonatal for Intratracheal Suspension at 15° to 30°C (59° to 86°F) in a dry place.

EDUCATIONAL MATERIAL: A videotape on dosing is available from your Burroughs Wellcome Co. representative. This videotape demonstrates techniques for safe administration of Exosurf Neonatal and should be viewed by health care professionals who will administer the drug.

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EX Y03216

Comparison of Nebulizer Delivery Methods through a Neonatal Endotracheal Tube: A Bench Study

Joseph L Rau Jr PhD RRT and Robert J Harwood MSA RRT

We compared the amounts of bronchodilator delivered through an endotracheal tube (ETT) to a laboratory model of the neonate requiring ventilatory support. METHODS & MATERIALS: Albuterol (Proventil) from a nebulizer driven by a 6 L/min gas flow was delivered in three ways. In Method 1, the nebulizer was placed just proximal to the patient Y on the inspiratory limb of a ventilator circuit. In Method 2, the nebulizer was placed in-line on the inspiratory limb of a ventilator circuit with a 5-inch reservoir tube between the nebulizer and the patient Y. In Method 3, the outlet of the nebulizer T-piece was connected directly to the ETT. With the first two methods, ventilation was provided with a Seehrist IV-100B neonatal ventilator, using continuous-flow and pressure-limited ventilation. In Method 3, nebulized drug was delivered by manually inflating the lung model. Uniform ventilator settings were used with all three methods: rate 30 breaths/min, inspiratory time 0.5 s, and peak inspiratory pressure 20 cm H_2O. Aerosolized drug delivery at the end of the ETT was measured using a spectrophotometric technique. RESULTS: The nebulizer proximal to the Y delivered 0.97% of the total dose placed in the nebulizer reservoir to the end of the ETT. The use of the reservoir tubing increased this to 1.78% of the dose. Manual inflation resulted in delivery of 1.03% of the dose. Drug delivery was significantly greater with use of reservoir tubing than with the other two methods ($p < 0.05$), which did not differ from each other. CONCLUSION: The presence of a 5-inch reservoir between the gas-powered nebulizer and the Y adapter on the inspiratory limb of the ventilator circuit significantly increases the aerosolized bronchodilator delivered through a neonatal ETT, although only a small fraction of the total dose is delivered with any of the three methods examined. (Respir Care 1992;37:1233-1240.)

Introduction

For the treatment of pulmonary problems in mechanically ventilated infants, the delivery of drugs as aerosols offers several advantages. These include rapid onset, lower doses compared to those required for systemic routes, reduced side effects, and demonstrable local effect on the target organ.[1-5]

Aerosol delivery of drugs to this population of patients is complicated by the number of factors that can affect the actual dose of drug reaching the lungs. Those factors include ventilatory variables, the exact type of aerosol generator, the patient-generator interface, and the size of the endotracheal tube. However, a 1991 study by Benson and coworkers found that ventilatory variables such as type of ventilator, peak pressure, and respiratory rate do not have a significant effect on aerosol delivery to an intubated neonatal lung model.[6]

Evidence is accumulating to suggest that the size of the ETT may be a major factor, with reduced drug delivery occurring as ETT diameter decreases.[7,8] Aerosol delivery through ETTs appropriate for neonates has been shown to be much less than the accepted figure of 10% given for spontaneously breathing nonintubated subjects.[9,10] Delivered amounts have been measured in the range of 0.02-1.96%.[11-14] In neonatal ventilation, aerosol delivery

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is further complicated by use of continuous-flow, pressure-limited modes of support. Placement of a nebulizer in the ventilator circuit with continuous flow can result in washout of drug during both the inspiratory and expiratory phases.

A survey by Salyer and Chatburn on methods of administering aerosol to neonates during mechanical ventilation reported that 54% of respondents administer aerosol in-line at the patient Y, 24% administer in-line on the inspiratory limb some distance away from the Y, and 22% use a manual inflation method.[15]

We found no data on the relative efficiency of these methods as a guide for clinical practice. In order to quantitate the efficiency of these methods, we applied the technique of spectrophotometric analysis to measure the amount of a bronchodilator drug reaching the 'tracheal' end of the ETT, in a neonatal lung model.

We compared the amount of bronchodilator drug delivered to the end of the ETT by each of three methods of administering aerosol drug from a gas-powered nebulizer.

Methods and Materials

Study Design

A model was employed to compare three methods of delivering nebulized bronchodilator to ventilated neonates. A Sechrist IV-100B neonatal ventilator* was used in the pressure-limited, continuous-flow mode, with settings: flow 10 L/min, respiratory rate 30/min, inspiratory pressure 20/0 cm H_2O, inspiratory time = 0.5 s, and inspiratory-to-expiratory-time ratio (I:E) 1:3. A low-compliance neonatal ventilator circuit supplied by the ventilator manufacturer was connected to the ETT with a right-angle 15-mm female adapter. The humidifier was bypassed for all trials, and a filter was placed on the expiratory limb to prevent drug contamination of the exhalation valve. The distal end of a 3.0-mm-ID ETT was connected to a small balloon with a Bird 3/16-in × 15-mm adapter. The end of the ETT was inserted into the 3/16-in adapter of the Bird fitting. The neck of the balloon was then fitted over the 15-mm end of the Bird fitting. The tidal volume of the balloon approximated 30 mL, based on its water-fill capacity and the fact that the inspiratory pressure used did not noticeably distend the balloon beyond this size. The expiratory pressure of zero cm H_2O allowed almost complete deflation of the balloon from this capacity. Manual breaths were delivered to the same pressure limit and approximate inflation of the test lung, with excessive volume vented through the pressure-relief valve. Pressure in the circuit dropped to zero cm H_2O when the anesthesia bag was released.

We placed 0.5 mL of albuterol sulfate solution 0.5% (Proventil) and 2.5 mL of 0.9% saline into gas-powered nebulizer. The nebulized drug was administered using each of three different methods. In Method 1, the nebulizer was placed in the inspiratory limb of the ventilator circuit just proximal to the patient Y (if one considers the ventilator to be the point of reference) and powered by a 6 L/min flow of compressed air (Fig. 1-A). Ventilator inspiratory pressure was maintained by reducing ventilator flow to 4 L/min, with the other settings unchanged. In Method 2, the nebulizer was placed in-line on the inspiratory limb of the ventilator circuit, with a reservoir of large-bore tubing (approximately 5 inches in length) between the nebulizer T and the Y (Fig. 1-B). The volume of the reservoir tubing was approximately 50 mL. Ventilator settings were the same as in Method 1. In Method 3, the nebulizer T-piece was attached directly to the ETT, and aerosol was delivered by manual inflation of the lung model with a 0.5-L anesthesia bag equipped with a manometer attached to the bag adapter, with approximately the same inspiratory pressure of 20/0 cm H_2O and a rate of 30 breaths/min (Fig. 1-C). Flow to the nebulizer was used to maintain bag inflation and ventilating pressure. An adjustable pressure-relief valve on the bag adapter allowed regulation of the inspiratory pressure to the same level as with the ventilator.

Five nebulizers of the same make and model (Intec Fan Jet) were used with each method of delivery. To minimize variability due to different nebulizers, the same five nebulizers were used in all three methods of administration, with one trial of each nebulizer in each method. This gave five measurements of drug delivery for each of the three

*Suppliers are identified in the Product Sources section at the end of the text.

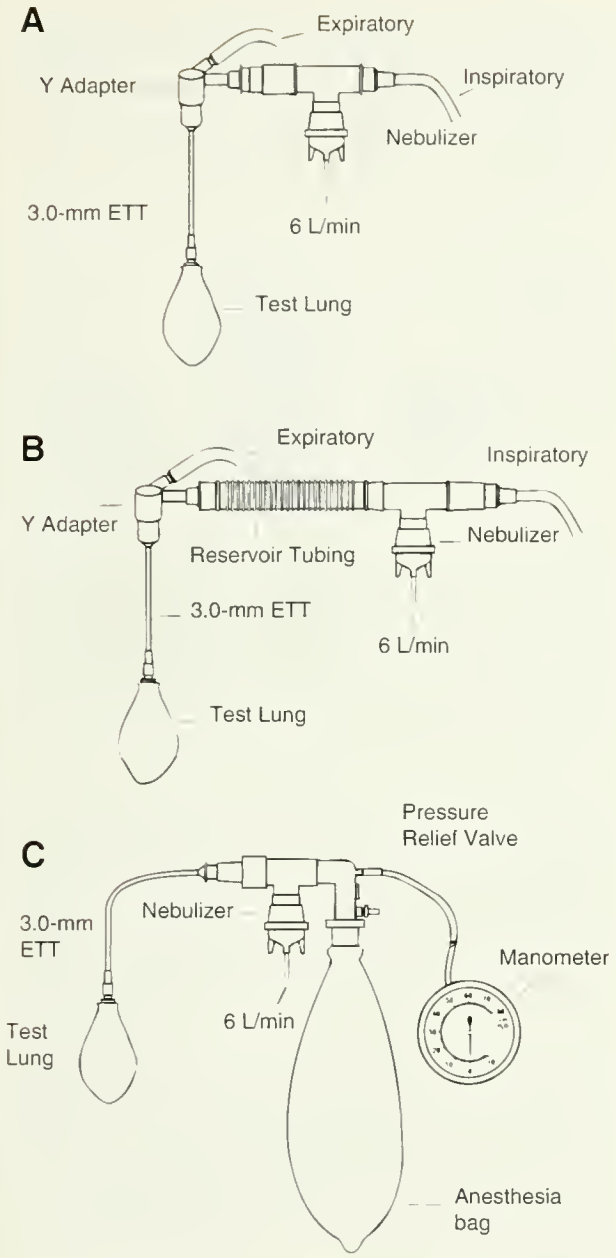

Fig. 1. Illustration of the three methods used to administer nebulized bronchodilator to an intubated lung model. A = Method 1; B = Method 2; C = Method 3.

methods of aerosol administration. The nebulizers were thoroughly rinsed and dried after each of the three uses, so that no residual drug remained to increase subsequent concentrations. All nebulizers were operated continuously at 6-L/min driving flow until sputter, at which time the nebulizer was tapped and operated again until sputter. Total time of nebulization was approximately 6 to 8 minutes for all nebulizers.

Measurement

A spectrophotometer was used to determine the amount of drug delivered to the end of the ETT. A standard solution of 0.005% (0.05 mg/mL) pure albuterol sulfate was prepared by dissolving the sulfate in 0.9% saline. This solution had an absorbance of 0.35 at a wavelength of 278 nm when scanned with the spectrophotometer. The scan of this standard solution agreed well with published spectral properties of albuterol sulfate.[16] Unknown concentrations of the drug were then calculated from the absorbance of the known solution. Prior to our measuring a sample, we adjusted the spectrophotometer absorbance to zero with the saline solvent alone.

Cotton wadding was carefully inserted into the 15-mm end of the Bird adapter connecting the ETT to the test balloon. The tip of the ETT rested just above the cotton to trap nebulized solution. Undue compression of the cotton was avoided, and volume distention of the balloon was not visibly altered. In separate measurements with a volume ventilator, the cotton increased ventilating pressure by no more than one or two cm H_2O, indicating little added resistance to gas flow (and, therefore, volume exchange) when the pressure-limited mode was used.

Drug was extracted from the cotton using 0.9% saline as a solvent. The resulting solution was then filtered through a slow-flow paper filter of medium porosity to remove any cotton fibers or other impurities that might affect the absorbance reading. Absorbance of this filtered solution was measured at 278 nm, and the amount of drug contained was calculated based on the known standard solution as follows:

$$C_{samp} = (A_{samp}/0.35)(0.05),$$

where C_{samp} is the concentration of drug in the sample in mg/mL, A_{samp} is the absorbance of the sample, and 0.35 and 0.05 are the absorbance and concentration (in mg/mL), respectively, of the standard solution of the drug.

The absorbance of a saline extract of the cotton alone with no drug was also measured and found to be 0.05, and this value was subtracted from the absorbance of all extracted sample solutions.

The accuracy of the 0.5-mL dose of albuterol used in the nebulizers, which should give 2.5 mg of active drug, was checked by measuring the absorbance at 278 nm of 5 test doses, using the manufacturer-supplied dropper. The amount of drug in the 0.5-mL dose was then calculated as indicated, using the concentration and absorbance of the reference solution. The same dropper was used in all trials of the three methods of nebulizer delivery. Based on this analysis, the average dose in milligrams from the 5 test doses was calculated as 2.51 mg, which agrees closely with the predicted 2.5 mg amount given. Because this check showed almost exact agreement with the predicted amount of 2.5 mg, the percentage of drug delivered to the end of the ETT in the trials for the three methods was calculated from a total dose of 2.5 mg.

Aerosolized drug output of the five nebulizers when operated in-line in the breathing circuit was measured by placing cotton wadding at the outlet end of the nebulizer T and proximal to the patient Y adapter. Then drug delivery was subsequently measured with cotton placed at the end of the ETT, for each of the three methods of delivery described.

The efficiency of the cotton in capturing the drug was checked by placing a second cotton wadding immediately after the first, both at the nebulizer T outlet and at the end of the ETT. The second cotton showed no trace of the drug after correcting for the absorbance of the cotton extract alone.

Data Analysis

Differences among the three methods of nebulizer delivery were analyzed using a repeated measures analysis of variance (ANOVA), with follow-up pairwise comparisons performed using Duncan's multiple range test. A significance level of 0.05 was chosen for the analysis.

Results

The percentage of total nebulized dose reaching the end of the ETT varied significantly among the three methods of delivery ($p = 0.04$), and is illustrated in Figure 2. When the nebulizer was placed just proximal to the patient Y, the mean dose delivered was 0.97% of the total dose, with a range of 0.68% to 1.04% (SD = 0.15). The use of reservoir tubing between the nebulizer and patient Y resulted in delivery of 1.78% of the total dose , with a range of 1.36% to 2.76% (SD = 0.62). Manual inflation resulted in a mean percentage of 1.03%, with a range of 0.68% to 1.72% (SD = 0.42).

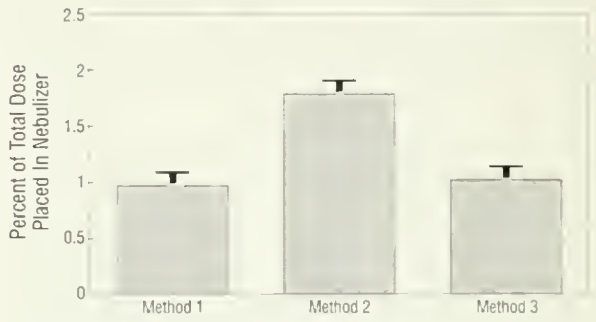

Fig. 2. Means and standard errors (SE) of the percent of total dose delivered at the end of the ETT by each of the three methods of nebulizer delivery. Method 1 = nebulizer in the inspiratory limb of the ventilator circuit. Method 2 = nebulizer in the inspiratory limb with a 5-inch reservoir between nebulizer T and circuit Y. Method 3 = nebulizer attached directly to endotracheal tube with aerosol delivered by manual inflation.

A follow-up comparison using Duncan's multiple range test indicated that the use of the reservoir tubing significantly increased nebulizer delivery compared to the other two methods ($p < 0.05$). There was no difference between the nebulizer placed proximal to the Y and manual inflation ($p > 0.05$).

The mean dose measured at the outlet of the nebulizer T when placed in-line was 27.1% of the total dose in the nebulizer (SD = 7.1%). The output of the five nebulizers used ranged from 17.0% to 37.0%. Approximately 70% of the total dose was lost in the nebulizer under the conditions employed.

Discussion

The percentage of an aerosol dose reaching the lung has been estimated at approximately 10% in nonintubated subjects, with either nebulizer or metered dose inhaler (MDI).[5,9,10,17] Although a significant difference was found between nebulizer delivery with a 5-inch reservoir tube placed in-line compared to the other two methods used, the total dose measured at the end of the ETT was much smaller than 10% in all three methods.

These results are consistent with previous studies of neonatal aerosol delivery.[1-5] Results from those studies are summarized in Table 1. The study by Ahrens and co-workers[8] reported a relatively high percentage of dose delivered to the lung model employed compared to other studies, including our own. This may reflect the use of the in-vitro methodology. In a study of nebulizer and MDI aerosol delivery to intubated adults, Fuller and associates[18] noted that laboratory bench studies seemed to find considerably greater deposition than in-vivo studies. There could be several reasons for this. Certainly, there is greater control of extraneous variables (such as coordination with patient breathing, amount exhaled, consistency of tidal volume, consistency of rate, and positioning of the nebulizer) in a laboratory study than in a critical care application. The study by Benson et al[6] also employed a laboratory lung model and reports the second highest percentage of delivery, of the studies listed in Table 1. Cameron and associates[13] found a delivery of less than 1%, although this was an in-vitro study. Our own results fall between the high values of Ahrens et al[8] and Benson et al[6] and those reported from the in-vivo studies of Banks et al[12] and Flavin et al.[11] The study by Arnon and co-workers[14] was similar to ours in the use of a Sechrist ventilator with continuous flow, pressures of 20/2 cm H_2O, and rate of 30/min. However that study evaluated the Ultravent submicronic nebulizer and the Swedish nebulizer MAD2, as well as MDI delivery with reservoir devices.[14] The extremely low delivery of 0.02% with the Ultravent may represent the loss of volume associated with decrease in particle size. Results with the MAD2 are comparable to ours. It should be noted that the measurement methodology varied among these studies, and included weighing of aerosol trapped on filters (Cameron), fluorometric assay (Ahrens), fluorescence polarization immunoassay (Benson), liquid chromatography (Arnon), and radiolabelled aerosol particles (Banks; Flavin). We used a method of spectrophotometric scanning. The variation in methodologies may contribute to variability among the reported results as well.

Table 1. Summary of Studies by Other Investigators on Aerosolized Drug Delivery through Neonatal Endotracheal Tubes

Study*	Device	ETT Size	% Delivered
Ahrens et al[8]	SVN	3.0 mm	8.5%
Arnon et al[14]	SVN-1‡	3.5 mm	0.02%
	SVN-2	3.5 mm	0.68%
Banks et al[12]	SVN	Unspecified	0.28%
Benson et al[6]	SVN	2.5 mm	2.11%
		3.0 mm	2.0%
		3.5 mm	2.14%
Cameron et al[13]	SVN	3.5 mm	0.69%
Flavin et al[11]	SVN	3.0 mm	0.19-1.9%

*First author and reference are indicated for each study.
‡SVN-1 = Ultravent; SVN-2 = MAD2.

The method of spectrophotometric scanning is particularly well suited to determining aerosol drug delivery and offers high accuracy while avoiding the problems associated with other forms of measurement. Weighing of drug mass trapped on filters is prone to error because of the small amounts involved. A 5-place balance (accurate to 10 μg) is required and can be affected by temperature, humidity, stability of the resting surface, and airflow. Contaminants such as condensed aqueous solution dripping onto the filter will increase the weight measured but do not represent drug mass. Radiolabeling techniques require scanning cameras and substance control of the radioactive isotopes. Immunoassay is expensive. In contrast, the spectrophotometric technique uses easily obtained solvents and readily available instrumentation. Once a standard absorbance has been measured with a known drug concentration, unknown concentrations can easily be calculated as a function of their absorbance. Pure powdered forms of albuterol, both the free base found in MDIs and the sulfate contained in nebulizer solutions, are readily available from chemical companies for preparation of the standard solution, as was done in our study. Our technique for determination of drug amounts delivered by aerosol has been used in unpublished studies but has not been noted in the literature. We have recently reported the same technique to evaluate MDI aerosol delivery with a commercially available reservoir device for in-line ventilator use.[19]

The most striking finding of the present study was the lack of difference in deposition between the in-line nebulizer placed proximal to the patient

Y and the manual inflation technique. We had expected that the continual flow through the patient circuit provided by the pressure-limited mode of ventilation would drastically decrease the delivered aerosol drug amount by washout of the nebulized drug. In contrast, manual inflation would eliminate this constant flow and subsequent washout. However, we saw no significant difference between the two methods. This provides some evidence that the primary factor reducing aerosol drug delivery through neonatal-size ETTs is the amount of baffling produced by the small ETT, rather than the ventilatory variables. If this is in fact the case, then inertial impaction is the physical mechanism by which drug is lost. This agrees with the findings of Benson and associates[6] that there was no significant difference between ventilator types, including both pressure-limited (BP 200, Bear Cub) and time-cycled volume-preset (Servo 900C) machines, for delivery of nebulized drug in a neonatal model.

Crogan and Bishop's study[7] of delivery efficiency of MDI aerosol through ETTs also supports ETT baffling as a significant mechanism for aerosol loss. Their study showed that 3.0% of a dose of MDI aerosol is delivered through a 6.0-mm ETT, while 4.7% and 6.5% are delivered through a 7.5-mm and 9.0-mm ETT, respectively. This direct relationship between ETT size and amount of aerosol delivery leads us to expect that neonatal airways pose a formidable barrier to aerosol drug delivery.

The use of the 5-inch reservoir between the nebulizer and the Y almost doubled the amount of aerosolized drug delivered through the ETT in comparison to the other two methods. This was despite the continual flow through the ventilator patient circuit. We can only speculate on reasons for this improved delivery. If inertial impaction is a major factor in aerosol loss with intubated subjects, the presence of the reservoir may allow particles to 'age.' This may allow both evaporation and some baffling, resulting in smaller, more consistent particle sizes. Impaction loss, a function of particle size and velocity, would be less. Our results are compatible with the study of Hughes and Saez,[20] which showed that placement of the nebulizer in an adult ventilator circuit at the manifold (ie, upstream from the Y-connector) presented significantly more aerosol medication to the ETT adapter. Their study did not measure the amount of aerosolized drug actually reaching the end of the ETT. Regardless of the exact mechanisms of improved delivery, we support adapting a reservoir for in-line nebulizer delivery of aerosol to mechanically ventilated neonates, based on these results.

Our study did not attempt to determine the optimum size of an in-line reservoir for nebulizer delivery to neonates on ventilatory support. A recent study by Quinn[21] showed that placement of the nebulizer as far back as the ventilator significantly increased drug delivery. Quinn's study, and that of Hughes and Saez,[20] utilized adult volumes, ventilators, and ETT sizes, which reduces or possibly eliminates the applicability of those studies' findings to neonatal ventilation. The finding that a reservoir increases aerosol delivery supports the importance of future investigations of this question. We used a 5-inch large-bore reservoir tube with a volume of approximately 50 mL because such a tube is readily available in clinical sites and is often included in commercial nebulizer packets. A recent study by Ebert and co-workers[22] showed that chamber-style reservoir devices (AeroVent, ACE) deliver greater amounts of drug in the respirable range than do either small in-line adapters or elbow adapters.

We did not investigate the effect of intermittent nebulization coordinated with the inspiratory phase only. The Sechrist ventilator used in the study does not offer a nebulizer power function, either continuous or intermittent. Further, inspiratory nebulization may not be feasible or efficient with the short inspiratory times and rapid rates of neonatal ventilation.

An additional variable that needs quantification is the effect of humidification on aerosol delivery. The humidifier was bypassed in our study. Humidification of the carrier gas may or may not affect particle size from the nebulizer. Hygroscopic growth in a warm, saturated environment could add to particle size and perhaps reduce aerosol delivery by increased baffling and impaction. This was the case in the adult model studied by O'Riordan et al.[23] However, nebulizer output is itself humidified through evaporation, and, in addition, ventilator flow is lowered by the nebulizer flow amount, reducing the addition of humidified ventilator gas.

The net effect in the neonatal configuration used in our study is difficult to predict. Kim and coworkers[24] showed insignificant change in MDI-aerosol particle size with humidification compared to no humidification in the carrier gas.

An interesting result of the study was the amount of drug actually delivered from the nebulizer outlet, which was measured as less than 30% of the total 2.5-mg dose. This is lower than the 34-59% found by Kradjan and Lakshminarayan[25] in their study of nebulizer efficiency. Shim and Williams[26] also reported that 40-52% of a 2-mL dose is actually delivered from a gas-powered nebulizer under conditions of usual clinical administration. Neither of these studies used conditions of in-line placement in a positive-pressure circuit with intubated subjects—conditions used in our study that may further decrease the efficiency of nebulizer output. We observed leakage during operation from all of the nebulizers with positive pressure. One of the five nebulizers in the study aerosolized only 17% of the total dose, indicating a variability in performance of the nebulizers. These findings agree with a recent study by Alvine and associates,[27] which found significant variability in efficiency of disposable nebulizers, with leaking of solution and air leaks that impeded nebulization. Their study did not use in-line placement in a positive-pressure circuit, placement that would be expected to increase leakage.

Another variable that could affect the efficiency of drug output from the nebulizer is the filling volume. Hess et al[28] showed that a 2.5-mL volume produced excessive dead volume, lowering the output of drug. Although we used a 3.0-mL volume, this could have been a partial cause of the low efficiency we observed. However, the Hess study did not examine the nebulizer used in our study (Intec Fan Jet) so we cannot be certain of this. In addition, the previously cited study by O'Riordan et al,[23] showed that increasing the volume fill from 2.0 mL to 3.0 mL actually decreased nebulizer output from 33 to 20.5% with the AeroTech II. The study by Hess et al[28] also showed a significant increase in duration of nebulization with increased filling volumes. Our choice of a 3.0-mL volume allowed a reasonable time for nebulization, important for neonatal application, especially with manual inflation. Our volume agreed with that used by Kradjan and Lakshminarayan in their study,[25] allowing a more direct comparison of efficiency with their results. That study also used a 6-L/min flowrate for powering the nebulizer.

One result that emerges from these findings of inefficient delivery of nebulized drug in a neonatal model is the need for aerosol-generating equipment tailored to the demands of neonatal delivery. The performance of gas-powered nebulizers in positive-pressure circuits in general deserves further investigation.

Conclusions

Only a small fraction of total available drug is delivered through ETTs in a neonatal model, regardless of the exact method of nebulizer delivery. Use of a reservoir with the nebulizer on the inspiratory limb of the ventilator circuit almost doubled the amount of aerosol drug reaching the end of the ETT. Gas-powered nebulizers are inefficient in delivering aerosol to the ETT, and output varies among individual nebulizers.

ACKNOWLEDGMENTS

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PRODUCT SOURCES

Bronchodilator:
Albuterol sulfate (Proventil), Schering Corp, Kenilworth NJ

Anesthesia Bag:
500 mL, Life Design Systems, Carrollton TX

Spectrophotometer:
Beckman Model 24 Double Beam Spectrophotometer, Beckman Instruments Inc, Fullerton CA

Manometer:
Model 145R, Bird Products Corp, Palm Springs CA

Endotracheal Tubes:
Armstrong Medical Products, Lincolnshire IL

Filter Paper:
No. P5, Fisher Scientific, Pittsburgh PA

Nebulizer:
Intec Fan Jet, Marquest Medical Products, Englewood CO

Circuit Filters:
Pall Breathing Circuit Filter BB-50T, Medical Devices Inc, Birmingham AL

Ventilator:
Sechrist IV-100B, Sechrist Industries Inc, Anaheim CA

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High Frequency Ventilation: Comparison of an Electronic Flow Interrupter and a New Pneumatic Oscillator

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BACKGROUND: We used a piglet model of respiratory failure to compare cardiopulmonary responses and pathologic effects on the airway mucosa and lung parenchyma of a combination of high frequency ventilation (HFV) and conventional breaths as provided by an electronic high frequency flow interrupter (HFFI) and a pneumatic oscillator (HFO). Unlike the HFFI, the HFO superimposed high frequency pulses on the conventional breaths. MATERIALS & METHODS: Twelve piglets (mean age 9 days, mean weight 2980 g), assigned at random to either ventilator, received lung lavage and 6 hours of ventilation (F_{IO_2} 1.0). Five additional piglets of similar characteristics received alternating HFFI and HFO. RESULTS: The combination of CMV and HFV was readily provided by both devices. Successful gas exchange was accomplished without cardiovascular compromise with either the well-known HFFI or the new pneumatic HFO. CONCLUSIONS: Absence of significant airway and lung injury suggests that the ventilatory strategies instituted resulted in alveolar recruitment and lung-volume maintenance. No beneficial effects of high frequency pulses superimposed on conventional breaths were observed in this study, but the unique capability of the pneumatic HFO to oscillate during lung inflations of different magnitudes and duration should be explored further. (Respir Care 1992;37:1241-1249)

Introduction

The Infant Star, a high frequency flow interrupter (HFFI), became commercially available in 1989.* Since that time, according to the manufacturer, "hundreds" of units have been in use, but the literature involving this ventilator remains sparse.[1,2] In addition, the FDA released a pneumatic high frequency oscillator (HFO, Oscillatron-1 Percussionator) for marketing in December 1990,[3] but so far the published experience with this device has also been scarce and preliminary.[4,5] Both devices can operate as conventional mechanical ventilators (CMV), high frequency ventilators (HFV), or in CMV/HFV combination. Unlike the HFFI, the HFO can superimpose high frequency pulses on the conventional breaths. This feature may represent a definite advantage because pulsatile, short, periodic inflations have been shown to promote alveolar recruitment and better oxygenation.[6,7]

We designed a study to compare the cardiopulmonary responses and pathologic effects on the airway mucosa and lung parenchyma of a combination of high frequency ventilation and conventional

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None of the authors has any financial interest in any of the products mentioned.

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*Suppliers are identified in the Product Sources section at the end of the text.

breaths as provided by the two ventilators in an experimental model of respiratory failure.[8] Also, a crossover study was conducted to compare the cardiopulmonary and airway effects of alternating between the two modes of high frequency ventilation.

Materials and Methods

Seventeen newborn piglets aged 7 to 14 days [mean (SD) 9 (4) days] and weighing 2.4 to 3.8 kg [mean (SD) 2.9 (0.9) kg] were included in this study, which was approved by the institutional Laboratory Animal Care and Use Committee. Eleven of the piglets were male and six were female. Two hours after separation from their sow they were given atropine, 0.01 mg/kg subcutaneously, and ketamine/acepromazine 10:1, 20 mg/kg intramuscularly, and they were intubated with a triple-lumen uncuffed HI-LO endotracheal tube (3.5-mm ID). Surgical preparation included cannulation of the femoral artery and vein and placement of a catheter via the right jugular vein into the ventricle for mixed-venous blood sampling and for the continuous infusion of 5 $mL \cdot h \cdot kg^{-1}$ of 10% dextrose in water mixed with ketamine (10 $mL \cdot h \cdot kg^{-1}$).

Heart rate and aortic and pulmonary artery blood pressures were continuously recorded; cardiac output measured via Swan-Ganz Catheter (5 Fr) and reported as cardiac index was determined in duplicate by thermodilution using 1 mL 5% dextrose in water at 26°C. The animals were placed in a servo-controlled radiant warmer, and rectal and blood temperatures were monitored. Determination of blood gases was made by a pH/blood gas system, and alveolar-arterial oxygen ratios were calculated from the alveolar air equation. Intrapulmonary shunts ($\dot{Q}_s/\dot{Q}_t$) were calculated by the method described by Ruiz et al.[9]

Airway pressures were measured at the junction of the ventilator and the endotracheal (ET) tube (proximal) and 5 mm above the distal tip through one of the intramural catheters. The lumen designed for jet ventilation remained occluded. To increase the frequency response of the system, the pressure-measuring catheter was filled with saline. The frequency response of this pressure-measuring system was flat up to 32 Hz.[8] Pressure signals from the transducer were displayed on a multichannel recorder after calibration with a water manometer. Mean airway pressure ($\bar{P}_{aw}$) was obtained by electronically damping the pressure signal.

Ventilators

Infrasonics Infant Star Ventilator (HFFI). The Infant Star is a time-cycled, pressure-limited ventilator with continuous- and demand-flow options for CPAP and intermittent mandatory ventilation (IMV) modes. Dual microprocessors are used to control all ventilator functions. One microprocessor controls ventilator operations; the other provides display information. The high frequency option (2-22 Hz) has a bank of 10 proportioning valves that open for 18 ms to generate each pulse, regardless of frequency. The pulse amplitude is a function of the air flow allowed to exit the proportioning valves. During expiration a venturi creates subambient pressures, so the device performs like an oscillator. Although an HFFI, this device has been termed a "quasi-oscillator."[1,2] The HFV option can be used independently or in combination with IMV. The I-E ratio (I:E) can be varied for both CMV and HFV modes. At 15 Hz, the I:E of each pulse is 1:2.7. Humidification was provided by a Fisher & Paykel MR630 unit.

Oscillatron-I Percussionator (HFO). This ventilator is a pneumatically powered combination of a time-cycled IMV unit and a high frequency oscillator (Fig. 1-A). Conventional ventilation waveforms can be modified by changes in inspiratory time, expiratory time, and inspiratory flowrate (peak inspiratory pressure). This device can be used for IMV, HFO, or a combination of both. High frequency oscillatory pulses are delivered throughout the IMV breath (Fig. 2). Source gases for the ventilator are 50 psig (2585 torr) air and oxygen routed through an oxygen blender with two outputs. One output can be adjusted by a regulator inside the ventilator and powers all ventilator controls as well as the inspiratory flowrate used in the IMV mode. The second output provides a continuous flow of inspiratory gas to the patient circuit.

The neonatal patient circuit consists of inspiratory, expiratory, and oscillatory limbs and a pressure-monitoring line. The oxygen blender provides a continuous flow through the inspiratory limb and

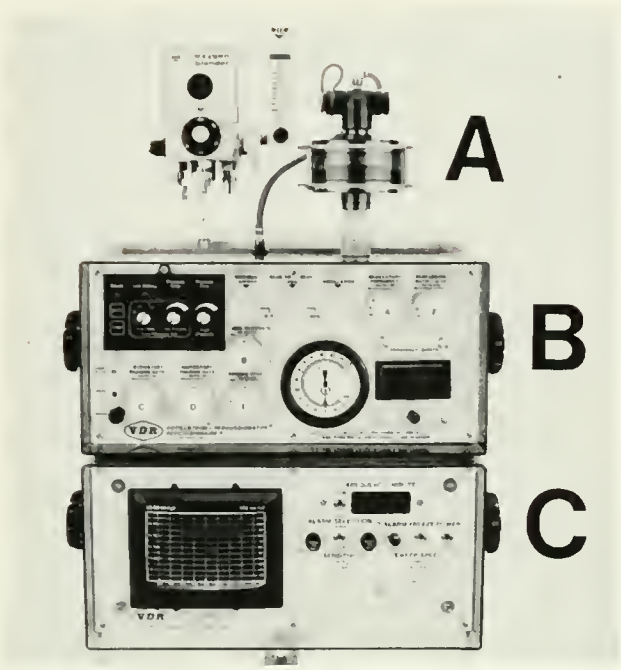

Fig. 1. A—Canister holding spring-loaded diaphragm; B—Oscillatron-1 Percussionator; C—Monitron Wave Form analyzer.

the additional gas needed to create peak inspiratory pressure when IMV is used. An overpressure valve and a heater-humidifier system are placed in-line with the inspiratory limb of the circuit. In this investigation a heat and moisture exchanger (HME) was placed between the circuit Y and the ET tube. The expiratory limb has an adjustable outflow valve that was used to provide baseline CPAP levels. High frequency oscillations were introduced into the circuit at the Y, contiguous to the airway pressure line.

The Oscillatron-1 Percussionator has a sliding venturi system (Phasitron) that functions as an inspiratory/expiratory valve and is housed inside the ventilator.[10] Oscillations are created by using the Phasitron to drive a spring-loaded diaphragm (Fig. 1-B), creating a push/pull action. Operator-adjustable variables are amplitude (up to 75 cm H_2O [7.35 kPa]), oscillatory rate (1.7-21.6 Hz), and symmetry of inspiratory-expiratory (I:E) high frequency pulse. The I:E for CMV and HFV modes can also be varied, but in the present study (10 Hz) I:E was kept at 1:1.

The ventilator measures and displays CPAP levels and peak inspiratory, mean airway, and amplitude pressures—using aneroid manometers. An optional oscilloscope (Monitron Wave Form Analyzer) was attached to the ventilator. This oscilloscope has variable sweep speeds and digital displays of IMV and HFV rates (Fig. 1-C).

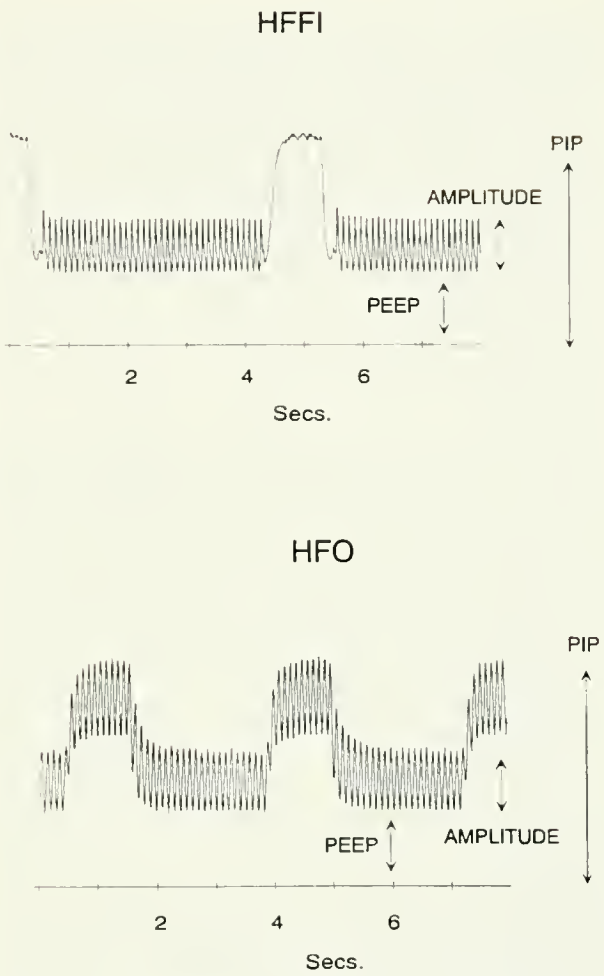

Fig. 2. High frequency waveforms used in this study.

Experimental Protocol

After insertion of arterial and venous lines, all animals were given pancuronium bromide, 0.02 mg/kg I.V., and were placed on CMV with F_{IO_2} 0.21. Lung lavage was accomplished using warm saline (37°C), 35 mL/kg, delivered and removed by gravity.[11] Ten 1-minute lavages were performed at 5-minute intervals. This technique has been shown to decrease static and dynamic compliance and to increase intrapulmonary shunt.[8,12]

Following lavage, 12 animals were randomized (flip of coin for each pair) into either HFFI or HFO

groups for 6 hours of continuous ventilation on F_{IO_2} 1.0. Blood gases were maintained at pre-established values (P_{O_2} > 100 torr [13.4 kPa], P_{CO_2} < 45 torr [5.99 kPa]) by adjustments of PEEP to maintain oxygenation and by increasing oscillatory amplitude for control of CO_2 elimination. The number of IMV breaths per minute varied from 10 to 30 depending on the individual animal's P_{aCO_2}. The ventilator frequencies arbitrarily selected were 10 Hz (HFO) and 15 Hz (HFFI).

Crossover

Five additional piglets chosen at random (flip of a coin) were started either on the HFO and then crossed over to the HFFI at hourly intervals or started on HFFI and then crossed over to the HFO. Similar $\bar{P}_{aw}$, PEEP amplitude, and IMV frequency were maintained during each crossover. Physiologic variables (heart rate, blood pressure, cardiac output, arterial blood gases) were recorded 15, 30, and 60 minutes after each ventilator change. After the initial 15-minute period, PEEP was adjusted as necessary to maintain blood gases at the pre-established values. In all animals, new ventilator settings were recorded and a 45-minute period elapsed before the next ventilator changes (opposite device) were made. All animals survived the experiment and were sacrificed with sodium pentobarbital and potassium chloride.

Pathology

At autopsy, the lungs of the animals that did not participate in the crossover study were inflated with formalin delivered by gravity at 40 cm H_2O [3.92 kPa] pressure. The position of the ET tube tip was noted at autopsy, and airway tissue cross-sections were taken from the midtrachea, carina, left and right mainstem bronchi (LMB, RMB), and left and right hilar bronchi (LH, RH). All tissue sections were formalin-fixed, paraffin-embedded, and cut at 5-μ thickness for hematoxylin-eosin staining. Two sections of parenchyma (RLL, LLL) were examined and the presence of congestion, intra-alveolar hemorrhage, pneumonitis, bronchiovascular hemorrhage, and edema was noted and scored for severity from 1 to 4. The presence of necrotic material plugging bronchioles was also recorded.

The severity of the airway injury was assessed by a scoring system that takes into account not only the type of lesion, but also its circumference and depth. The sum of products (circumference × depth) for each type of injury noted equals the airway injury score (AIS) for each airway level examined.[12] All airway sections were scored by one of the authors (BP) who was unaware of the treatment modality.

Statistical Analysis

To assess differences in the severity of airway injury between the two treatment groups, mean airway injury scores were compared using the Wilcoxon rank sum test. For the hourly derived variables, a Student's *t* test and analysis of variance for repeated measures were used. In all cases, a probability level of 95% ($p < 0.05$) was accepted to indicate significance. All data are reported as mean (SD).

Results

Physiologic Variables

For animals in the non-crossover phase of the study, heart rate, which was about 190 bpm following surgery, declined steadily throughout the study period to approximately 150 bpm (Table 1). Mean aortic pressure (55 torr [7.3 kPa]) and cardiac index (0.45 L · min · kg^{-1}) remained stable for most of the experiment. Following lung lavage, some animals from each group developed mild and transient metabolic acidosis. The establishment of high frequency ventilation with either device successfully provided oxygenation and adequate ventilation for all animals. Neither P_{CO_2} values for animals in the HFO group—which were somewhat lower throughout the latter part of the study—nor the remaining arterial blood gas values were different among animals of the same or of the opposite group. On the average, 5 (2) CMV breaths for HFO and 4.3 (3) CMV breaths for HFFI were needed to maintain pre-established P_{aCO_2} values. The differences in the rate of CMV breaths between the two ventilator groups were not statistically significant ($p > 0.50$). Arterial-alveolar O_2 ratios were similar for both treatment groups from the beginning to the

Table 1. Cardiovascular and Blood Gas Values* in 12 Piglets

	Lung Lavage				Hours into HFV†			
	Before‡		After‡		1st Hr		6th Hr	
	HFO	HFFI	HFO	HFFI	HFO	HFFI	HFO	HFFI
Heart rate (beats/min)	190 (9)	177 (19)	172 (36)	170 (26)	166 (27)	166 (21)	157 (11)	152 (12)
Mean aortic pressure (torr)	57 (9)	54 (3)	58 (5)	55 (12)	64 (13)	56 (11)	52 (7)	42 (17)
Cardiac index ($L \cdot min \cdot kg^{-1}$)	0.5 (0.4)	0.4 (0.5)	0.6 (0.3)	0.4 (0.4)	0.6 (0.4)	0.5 (0.2)	0.4 (0.3)	0.3 (0.2)
pH	7.4 (0.03)	7.4 (0.03)	7.32 (0.05)	7.39 (0.04)	7.33 (0.06)	7.27 (0.05)	7.32 (0.03)	7.34 (0.05)
P_{aCO_2} (torr)	35 (3)	36 (3)	36 (6)	30 (3)	36 (6)	42 (9)	41 (3)	35 (5)
P_{aO_2} (torr)	75 (20)	85 (13)	300 (127)	213 (35)	370 (150)	326 (107)	359 (120)	525 (34)
HCO_3^- (mEq/L)	22 (1)	22 (2)	19 (2)	18 (1)	19 (3)	19 (2)	20 (3)	18 (4)

*All values are mean (SD).

†ANOVA repeated measures ($p > 0.2$).

‡Animals breathed room air before lavage, 100% O_2 afterward.

end of the study (Fig. 3). After the first hour of HFV a significant and sustained improvement in arterial-alveolar oxygen tension ratios for the entire group of animals was noted.

Airway Pressures

On the average, amplitude measured proximally was 38 (13) cm H_2O [3.72 (1.27) kPa] for HFO and 43 (11) cm H_2O [4.21 (1.08) kPa] for HFFI. Similarly, during the conventional breath, proximally measured PIP was 57 (3) cm H_2O [5.59 (0.29) kPa] for HFO and 29 (8) cm H_2O [2.84 (0.78) kPa] for HFFI.

Airway pressures (cm H_2O) measured distally were PIP 34 (3) [3.33 (0.29) kPa], PEEP 15 (2) [1.47 (0.20) kPa], amplitude 34 (3) [3.33 (0.29) kPa], $\bar{P}_{aw}$ 14 (2) [1.37 (0.19) kPa] for HFO—and PIP 35 (7) [3.43 (0.69) kPa], PEEP 14 (2) [1.37 (0.19) kPa], amplitude 26 (8) [2.55 (0.78) kPa], $\bar{P}_{aw}$ 15 (2) [1.47 (0.19) kPa] for HFFI-treated animals. Throughout the study, no significant difference ($p > 0.5$) of the $\bar{P}_{aw}$ between the treatment groups was observed (Fig. 3). Amplitude controls reached upper limits in one of six HFO and five of six HFFI animals ($p < 0.05$).

Pathology

Lesions consistent with necrotizing tracheobronchitis were seen in all animals in the area of the trachea where the ET tube was located. These lesions extended to the carina in only three animals (1 HFFI and 2 HFO) (Table 2). Mean airway injury scores were 7.8 (6) for HFFI and 8.8 (3) for HFO. These differences were not significant (Wilcoxon rank sum test, $p > 0.5$).

Small amounts of necrotic material were seen in the bronchioles of one animal in each group. Microscopic examination of the parenchyma showed marked congestion and small alveolar hemorrhages in all animals regardless of mode of treatment. Because the lungs were inflated with formalin, the presence of atelectasis could not be evaluated. In addition, minimal polymorphonuclear infiltration

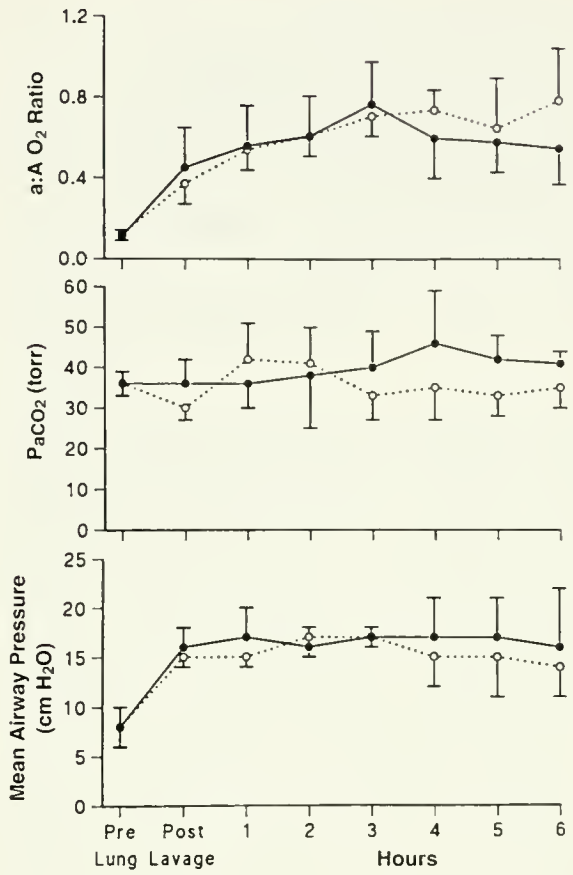

Fig. 3. Comparison of mean airway pressure, P_{aCO_2}, and a/AO_2 values between HFO (•—•) and (◦··◦) HFFI groups of animals [mean (SD)].

was noted in the parenchyma of four animals (2 HFFI, 2 HFO).

Crossover Studies

Physiological variables studied during the crossover phase of our investigation are presented in Table 3. By design, mean airway pressures at each crossover point were identical. No differences in cardiopulmonary or biochemical variables were observed immediately before or 15 minutes after the crossover was initiated (Table 2). It should be noted, however, that heart rates and blood pressures were higher than those reported for the longitudinal study in Table 1.

Discussion

Saline lung lavage is a widely used technique for surfactant depletion that produces a predictable

Table 2. Mean Airway Injury Scores (AIS) by Anatomical Location

	HFFI n = 6	HFO n = 6
Mid-trachea	4	6
Carina	2	1
LMB*	0	0
RMB	1	0
LH	0	0
RH	0	0
Combined AIS†	7.8	8.8

*LMB = left main bronchus; RMB = right main bronchus; LH = left hilum; RH = right hilum.
†No significant difference (Wilcoxon rank sum test $p > 0.5$).

model of respiratory failure in a variety of laboratory animals.[8,11,13] The lungs of newborn piglets have many morphologic and physiologic characteristics similar to those of the human neonate.[14] Thus, lung lavage in piglets provides an excellent model of respiratory failure, which lends itself well to evaluation studies of ventilatory devices and techniques.

In recent years, several hundred publications have addressed high frequency ventilation in humans as well as in animals.[1,2] Because new devices are being introduced frequently, the need for technical and clinical information remains intense. Often, operating characteristics of the ventilators, particularly their limitations, are inadequately described.[15,16]

In this investigation, basic operation of the ventilators was similar. Increases in PEEP resulted in better oxygenation, and increases in oscillatory amplitude and the addition of CMV breaths promoted CO_2 elimination. Like other investigators, we have observed that during high frequency ventilation, airway pressures measured proximally are much higher than those measured near the distal end of the ET tube.[17-20] Because the size of the ventilated subjects has been known to limit some ventilator function, it is not surprising that amplitude control reached upper limits in almost all animals in the HFFI group.

In spite of this limitation, our results showed that both of these high frequency ventilators were ca-

Table 3. Cardiovascular and Blood Gas Values* in 5 Piglets (Crossover Study)

	HFFI† to HFO‡		HFO† to HFFI‡	
Heart rate (beats/min)	215 (40)	→ 214 (45)	220 (33)	→ 208 (33)
Mean aortic pressure (torr)	74 (9)	→ 76 (9)	77 (13)	→ 76 (13)
Cardiac index ($L \cdot min \cdot kg^{-1}$)	0.5 (0.3)	→ 0.6 (0.2)	0.5 (0.4)	→ 0.6 (0.4)
$\dot{Q}_s/\dot{Q}_t$	0.25 (0.07)	→ 0.25 (0.09)	0.28 (0.12)	→ 0.32 (0.18)
pH	7.31 (0.06)	→ 7.32 (0.06)	7.31 (0.05)	→ 7.29 (0.05)
P_{aCO_2} (torr)	38 (7)	→ 38 (7)	38 (5)	→ 40 (6)
P_{aO_2} (torr)	384 (81)	→ 366 (98)	369 (120)	→ 360 (103)
HCO_3^- (mEq/L)	18 (2)	→ 19 (1)	19 (2)	→ 18 (1)

*All values are mean (SD).
†Measured immediately before crossover.
‡Measured 15 minutes after crossover.

pable of accomplishing adequate gas exchange without cardiovascular compromise. Animals in the crossover phase of the study presented higher mean heart rate and blood pressures than animals in the HFFI or HFO group. It is very likely that these cardiovascular differences were due to the fact that animals in the crossover phase were stressed more by switching back and forth between devices and by more frequent blood sampling.

The main operational difference between the two devices was the ventilatory frequency (HFO = 10 Hz, HFFI = 15 Hz). Our frequency selection (albeit arbitrary) was based on a substantial human experience with the same HFFI and on a large animal experience with high frequency pneumatic ventilators.[8,12]

The institution of a combined CMV and HFV strategy was based on the evidence that CMV would recruit alveoli at peak inspiration and HFV would maintain the alveoli open longer.[15,21,22] It is worth noting that no instances of lung rupture occurred in any of the 17 animals treated with HFV and backup IMV breaths with either ventilator.

The effects of sustained inflations of different duration and pressure magnitude on alveolar recruitment have been previously investigated. Walsh et al[23] studied surfactant-depleted rabbits treated with HFO and concluded that a critical pressure (at least 10 cm H_2O above $\bar{P}_{aw}$ for at least 10 s) was needed to obtain adequate oxygenation. Byford et al[6] reported that in atelectasis-prone rabbits, 90% of the changes in lung volume occurred during the first 5-10 seconds of sustained inflation. More recently, Watanabe et al[7] reported that, in surfactant-depleted rabbits undergoing HFO, repeated sustained inflation of 1-5 seconds and 25-30 cm H_2O airway pressures increased P_{aO_2} and lung volume without hemodynamic fluctuation. In light of the above, it is tempting to speculate that the tidal breath used in this study, although short, may have had a beneficial effect.

Byford et al[6] have also shown that delivery of high frequency pulses throughout a sustained inflation consistently increased lung volume and P_{aO_2} more than did static sustained inflation, with less risk of pulmonary barotrauma or cardiovascular compromise. No beneficial effects of high frequency pulse superimposed on conventional breaths were observed in our study, but the unique capability of the pneumatic HFO to oscillate during lung inflations should be explored further.

The presence of airway mucosal injury in the trachea of intubated animals has been observed regardless of mode of ventilation.[1] While some of the

lesions are associated with proximity to the ET tube, necrotizing tracheobronchitis (NTB) is characterized by more distal pathological changes. The more severe the injury, the more distal the compromise and the higher the mean airway injury score.[12] Although multifactorial in origin, NTB has been observed more frequently with some types of high frequency ventilation and with some specific strategies.[12,24,25] In spite of the short duration of the experiment, the absence of significant NTB lesions in the animals reported here is reassuring. Furthermore, it suggests that the use of an HME did not invalidate our results.

Conclusions

An electronic HFFI and a pneumatic HFO successfully ventilated a piglet model of respiratory failure, without cardiopulmonary compromise. A combination of CMV and high frequency ventilation was readily provided by both devices. The absence of significant airway and lung injury suggests that the ventilatory strategies employed must have resulted in alveolar recruitment and lung-volume maintenance.

ACKNOWLEDGMENTS

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PRODUCT SOURCES

High Frequency Flow Interrupter:
Infant Star Neonatal High Frequency Ventilator, Infrasonics Inc, San Diego CA

High Frequency Oscillator:
Oscillatron-1 Percussionator, Percussionaire Corp, Sand Point ID

Wave Form Analyzer:
Monitron, Percussionaire Corp, Sand Point ID

Triple-Lumen Endotracheal Tube:
NCC, Mallinckrodt, St Louis MO

Thermodilution Calculator:
American Edwards 9520 A, Baxter Healthcare, Irvine CA

Radiant Warmer:
Air Shields, Model DR, Air-Shields Vickers, Hatsboro PA

Blood Gas Analyzer:
Radiometer ABL 2 RA, Radiometer America Inc, Westlake OH

Pressure Transducer:
Gould P23 ID, Gould Inc, Cleveland OH

Heated Humidifier:
Fisher & Paykel MR630, Baxter Healthcare Corp, Valencia CA

Heat and Moisture Exchanger:
Humid-Vent 1, Gibeck-Dryden, Indianapolis IN

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Effects of Lithium Heparin Concentration on Whole Blood Analytes Measured on a Multichannel Blood Gas/Electrolyte System

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BACKGROUND: Current-generation multichannel blood gas electrolyte analyzer systems (MBGES) have the ability to measure blood gases & electrolytes simultaneously. The proposed volume of sample required to achieve this is as little as 1.8 mL. Previous studies have identified inaccuracies & imprecision of blood gas and electrolyte results caused by anticoagulants & small sample size. However, the effects of these two variables on measured analyte parameters have not been addressed for simultaneous measurements on current-generation MBGES. We designed a prospective study to quantify errors introduced into blood gas & electrolyte measurements by sample size & concentration of dry lyophilized heparin during simultaneous analysis using a Corning 288 MBGES. METHODS: Arterial blood was collected from an arterially cannulated 33-year-old healthy Caucasian man. Seventy samples of blood were removed, comprising 10 randomly ordered sets of 0.2, 0.4, 0.6, 0.8, 1.0, 2.0, & 3.0 mL of blood; the resulting specimens contained ~ 250, 125, 83, 63, 50, 25, & 17 IU of lithium heparin to 1.0 mL of blood, respectively. Sodium, potassium, ionized calcium, pH, P_{aO_2}, P_{aCO_2}, & total hemoglobin were all measured according to criterion standard for arterial blood gas analysis, collection, & calibration. RESULTS: Using analysis of variance & the Scheffe test, small sample volumes/high heparin concentrations resulted in lower sodium ($p < 0.001$) & ionized calcium ($p < 0.001$) and higher P_{aO_2} ($p = 0.03$) values. No variations were found in potassium, P_{aCO_2}, or total hemoglobin. Sodium & ionized calcium concentrations are underestimated in sample volumes of < 0.6 mL with lithium heparin concentrations > 83 IU/mL. CONCLUSION: When standard samples are used with MBGES, we recommend a minimum 0.6-mL sample size for accurate & precise blood gas & electrolyte values. (Respir Care 1992;37:1250-1255)

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Introduction

Abnormal concentrations of serum sodium, potassium, or calcium can have deleterious effects on the stability and well-being of the critically ill patient. Rapid response with fluid and electrolyte management can reverse and may prevent such disorders. Until recently, clinical decisions regarding the management of electrolyte balance have been based on laboratory values derived from indirect methods using flame photometry on prediluted specimens.[1] Recent improvements in ion-selective electrode technology have made it possible to measure sodium, potassium, and ionized calcium by direct potentiometry in their undiluted matrix. New-generation ion-selective electrodes have important advantages over indirect methods, notably speed, small sample volume, and easier use with whole blood specimens.[2] Use of the multichannel blood gas/electrolyte system (MBGES) at or near the critical care bedside[3] can provide a full battery of tests, requiring as little as 0.2 mL of whole blood.[4,5] This provides rapid cardiorespiratory and fluid-electrolyte diagnostic information, which may result in more timely therapeutic intervention while minimizing blood loss to the patient.

Use of these newer instruments, however, has raised new concerns regarding sensor calibration, sample handling, and sample collection.[3] Technique-related heparin dilution,[6,7] syringe dead space and air-bubble contamination,[8] sample storage and transportation,[9,10] and choice and concentration of anticoagulants have all been reported to contribute to errors in either blood gas or electrolyte analysis.[11-15] It is appropriate to differentiate techniques for blood gas as opposed to electrolyte handling because they have previously not been drawn from the same whole blood sample nor analyzed on the same instrument. With the development of MBGES, studies are required to assess the appropriateness of using conventional blood gas sampling techniques to also obtain specimens for electrolyte estimation.

Previous studies have not evaluated the applicability of blood gas sampling and handling techniques related to simultaneous electrolyte measurements. We conducted a prospective study to quantitate errors outside of normal limits introduced into blood gas and electrolyte measurements by sample size and concentrations of dry lyophilized heparin analyzed on a MBGES.

Methods

A 33-year-old Caucasian man with no previous history of smoking or respiratory or metabolic disorders volunteered and gave informed consent to participate in the study. Before and after the study, 7 mL of blood was sent to the central laboratory to obtain reference for normal electrolyte, lipid, and liver-function test values. The subject assumed a passive semireclining position adjacent to the MBGES. Blood pressure, heart rate, respiratory rate, and oral temperature were recorded at the beginning of each of the sample sets (explanation follows). The subject's left radial artery was cannulated with sterile technique using a 20-gauge, 2-inch Teflon catheter. This was capped with a 5-inch extension-T setup containing a heparinized normal saline solution (1.0 IU/mL) and a two-way stopcock. The total volume for priming this setup was 0.5 mL.

Concentration of heparin was determined by blood sample size. Standard commercially prepared blood gas sampling syringes were used. Each syringe contained a single 50-IU pledget of dry lyophilized lithium heparin when mixed with 1 mL of whole blood. Seven whole blood sample sizes of 0.2, 0.4, 0.6, 0.8, 1.0, 2.0, and 3.0 mL were equivalent to 250, 125, 83, 63, 50, 25, and 17 IU of heparin per 1.0 mL, respectively. In order to prevent excessive blood loss to the subject, sample numbers were restricted to 10, resulting in 10 data sets for each sample size with its corresponding heparin concentration.

Ten sample sets, each comprising 7 syringes (Samples 1-7), totalling 70 syringes, were prepared and labelled prior to the study as follows. In each of the 10 sets, 5 of the 7 sampling syringes (Samples 1-5) were taken unaltered from the manufacturer's packaging. These syringes comprised 50 of the total 70 sampling syringes. The remaining 20 syringes for Samples 6 and 7 in each of the 10 sets were prepared by removing the 50-IU heparin pledget from 1-mL TB syringes to 3-mL heparin-free syringes, thus enabling 2-mL and 3-mL blood samples to be drawn for Samples 6 and 7 in each of the 10 sets.

*Suppliers are identified in the Product Sources section at the end of the text.

Approximately every 4 minutes, a single arterial blood sample was drawn and debubbled, in the following manner. A sterile gauze pad was placed under the stopcock. The stopcock cap was removed and placed on the sterile pad. 1 mL of blood was withdrawn and discarded prior to each sample to ensure a patent, free system and to remove the 0.5 mL of flush from the catheter-extension-T setup.[7] One of the 70 samples was then drawn. The order of sampling was randomly established and stratified in the 10 sets of 7 samples.[16] This minimized errors due to the sampling technique, metabolism, or instrumentation drift. The specimen was then analyzed with full specimen procedure on the MBGES. This mode provided partial pressure of arterial carbon dioxide (P_{aCO_2}), partial pressure of arterial oxygen (P_{aO_2}), pH, total hemoglobin (THb), sodium, potassium, and ionized calcium measurements. Blood gas units were recorded in torr, THb in g/L—and sodium, potassium, and ionized calcium were recorded in mmol/L. The arterial line was flushed with 1 mL of heparinized normal saline (1.0 IU/mL) after each sample. Following each of the 10 sets, the line was flushed with 5 mL of heparinized normal saline (1.0 IU/mL), and 1.5 mL of blood was then removed prior to the first sample of the next set. This was done as an extra precaution to verify patency of the system. With the exception of a 2-point calibration after each set, this procedure continued without interruption until all 7 syringes in each of the 10 experimental sets were completed.

It took 4 hours to draw all 70 samples. Total blood loss to the subject was 155 mL, of which 75 mL was discarded. During this time the subject remained in a relaxed and steady state (heart rate 60-64 beats · min^{-1}, respiratory rate 14-20 breaths · min^{-1}, systolic/diastolic blood pressure 95-115/60-75 mm Hg, oral temperature 35.8-36.4°C). The subject's values for electrolyte, lipid, and liver function were all within normal limits.

Appropriate calibration and quality control procedures for blood gas and ion-selective electrode analyzers were observed.[17-19] Pre-packaged quality controls for this instrument are performed every 12 hours. Ten minutes prior to the study, Level 2 quality control (normal range) was run, and all values were within one standard deviation of expected values as supplied by the manufacturer.

Statistical Analysis

Descriptive and inferential statistics were calculated using commercially available software. The level of significance was set at < 0.05. Each of the 7 analyte parameters had 10 measurements, ie, one from each of the 10 sets. Descriptive statistics were then calculated for these 10 measurements for each analyte parameter in the 7 different manipulated samples (lithium heparin concentration). Analysis of variance (ANOVA) was used to compare the 7 sample groups.[20] Both one-way parametric and nonparametric ANOVA tests were utilized, but the more conservative non-parametric Kruskal-Wallis test was referred to for levels of significance for inferential statistics.[20] The Scheffe test (95% intervals) was performed to verify differences between sample sets.[20]

Results

The use of small sample volumes containing high concentrations of heparin resulted in underestimation of both sodium and ionized calcium. With sample volumes ≥ 0.6 mL (≤ 83 IU of heparin/mL), mean sodium serum ranged from 135.8 to 137.2 mmol/L. In the 0.4-mL sample (125 IU heparin/mL), the mean sodium was 134.5 mmol/L, and in the 0.2-mL sample (250 IU heparin/mL), it was 132.2 mmol/L ($p < 0.001$, Fig. 1). Similarly, for samples ≥ 0.6 mL, ionized calcium estimation ranged from 1.20 to 1.25 mmol/L, whereas at the smaller sample volumes calcium was underestimated at a mean of 1.16 and 1.01 mmol/L, respectively ($p < 0.001$, Fig. 2) (Table 1). In contrast, estimates of P_{aO_2} were significantly higher in the 0.2-mL sample (mean 98.8 torr [13.2 kPa]) compared to the larger samples, in which the means ranged from 91.2 torr [12.2 kPa] to 94.9 torr [12.6 kPa] ($p = 0.03$, Fig. 3). Values for pH, P_{aCO_2}, THb, and potassium did not vary significantly between the groups. It is also notable that the variances of P_{aO_2}, ionized calcium, and sodium in the 0.2-mL samples were much greater than in the larger sample volumes (Figs. 1-3). Acceptable precision levels set by the manufacturer for this instrument were exceeded for Ca^{++} in the 0.2-mL sample ($\pm$ 0.10 mmol/L). The use of sample volumes < 0.6 mL and

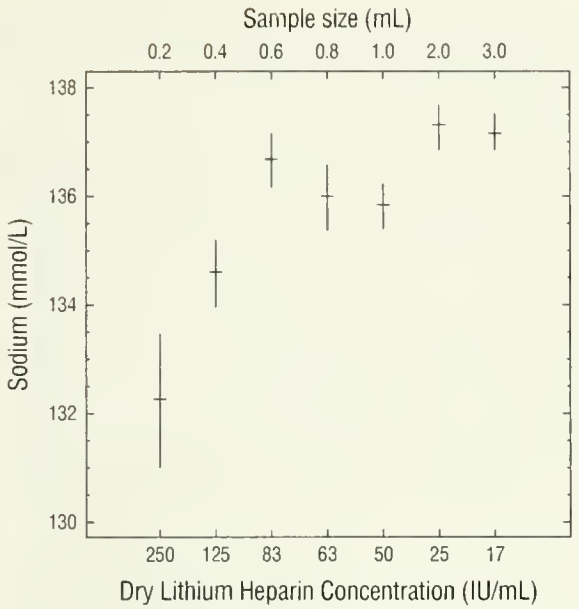

Fig. 1. Mean (horizontal lines) and standard error (vertical lines) values for sodium with various sample sizes and dry lithium heparin concentrations.

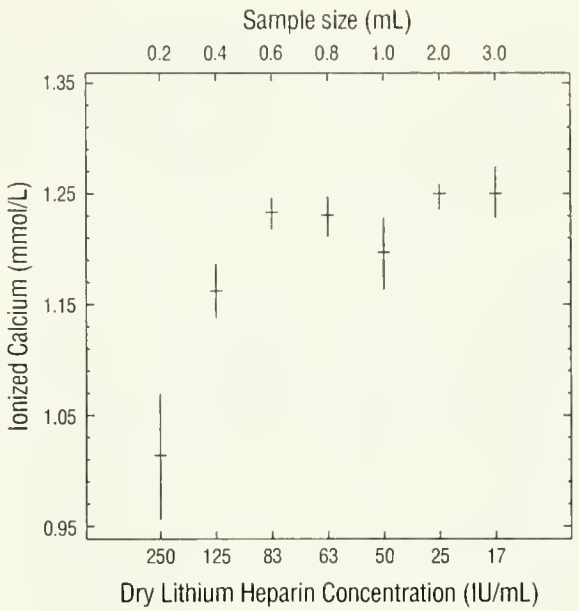

Fig. 2. Mean (horizontal lines) and standard error (vertical lines) values for ionized calcium with various sample sizes and dry lithium heparin concentrations.

standard sampling tubes containing 50 IU heparin per syringe introduces significant error in the accuracy of sodium and ionized calcium measurements. Precision for Ca^{++} is also compromised in the 0.2-mL samples.

Discussion

Estimates of ionized calcium were significantly less accurate and less precise in samples containing more than 83 IU heparin/mL of blood. Er-

Table 1. Means, Standard Deviations, and Ranges of Variables Measured on MBGES for Seven Different Sample Groups (n = 10)

	Sample 1 250 IU (0.2 mL)	Sample 2 125 IU (0.4 mL)	Sample 3 83 IU (0.6 mL)	Sample 4 63 IU (0.8 mL)	Sample 5 50 IU (1 mL)	Sample 6 25 IU (2 mL)	Sample 7 17 IU (3 mL)
pH	7.40-7.44	7.41-7.44	7.41-7.44	7.41-7.43	7.41-7.45	7.41-7.45	7.41-7.43
P_{aCO_2} (torr)	39.2 (2.7)*	38.2 (2.6)	37.2 (2.5)	38.7 (2.3)	38.1 (2.0)	37.2 (1.7)	38.8 (1.4)
	34.2-43.0	33.8-42.8	33.6-43.1	35.1-42.4	33.2-40.2	34.6-40.4	37.1-40.4
P_{aO_2} (torr)	98.8 (6.4)	92.8 (6.0)	93.0 (5.3)	91.8 (3.0)	94.9 (5.2)	93.9 (3.9)	91.2 (2.4)
	92.8-111.2	85.1-102.4	85.1-104.1	86.9-96.5	85.7-101.1	85.2-98.6	86.2-93.7
THb (g/L)	158.1 (1.8)	155.4 (4.0)	156.8 (3.6)	155.9 (4.0)	156.1 (2.8)	157.4 (1.3)	156.5 (2.0)
	156-161	146-160	149-162	145-159	152-162	156-159	153-159
Na^+ (nmol/L)	132.2 (1.4)	134.5 (2.0)	136.6 (1.5)	135.9 (1.9)	135.8 (1.3)	137.2 (1.3)	137.2 (1.1)
	131.6-136.1	131.4-137.3	133.4-138.3	132.5-139.4	133.1-137.6	135.1-139.1	135.2-139.0
K^+ (nmol/L)	4.14 (0.40)	4.04 (0.21)	4.00 (0.12)	4.04 (0.15)	4.03 (0.17)	4.04 (0.11)	4.02 (0.12)
	3.93-5.25	3.77-4.42	3.82-4.25	3.82-4.24	3.81-4.34	3.92-4 22	3.83-4.23
Ca^{++} (nmol/L)	1.01 (0.17)	1.16 (0.08)	1.23 (0.005)	1.23 (0.06)	1.20 (0.11)	1.25 (0.04)	1.25 (0.07)
	0.76-1.24	0.96-1.31	1.13-1.31	1.17-1.33	0.96-1.33	1.20-1.32	1.06-1.32

*Values are mean (SD).

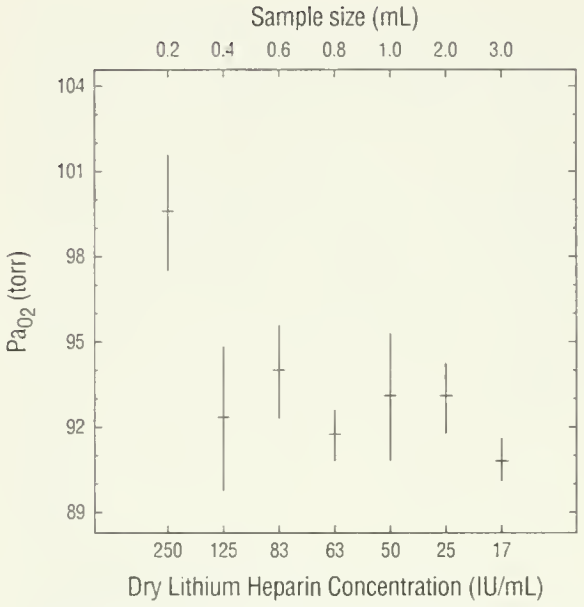

Fig. 3. Mean (horizontal lines) and standard error (vertical lines) values for P_{aO_2} with various sample sizes and dry lithium heparin concentrations.

rors of the magnitude found in the study might lead to inappropriate clinical decisions. These data are in agreement with previous studies performed using other measurement techniques, which indicate that excess lithium and sodium heparin will cause binding of calcium ions and artificially depress the measured value.[11-13] It is possible that this may be overcome by using calcium-titrated or electrolyte-balanced heparin. It remains, however, to be verified whether this can be utilized for MBGES.[14] Had we used treated heparin in the present study, the small sample volume/high heparin concentration samples might have given normal results, but for higher sample volumes this might have resulted in overestimation. We caution against the use of these alternative sampling techniques until further studies can verify their effects on all different sample sizes when using MBGES.

Analysis of sodium estimations revealed essentially the same pattern as that observed for ionized calcium: Heparin concentrations > 83 IU/mL significantly lowered the sodium value. This has not been addressed previously, but one may hypothesize a similar mechanism to that for the errors in ionized calcium calculations. Sodium in the sample may bind to heparin, resulting in a significant depression in measured sodium. It is of interest that this extrapolation did not result in a depression of potassium concentrations, and we cannot offer an explanation for this.

Overestimation of P_{aO_2} has previously been attributed to equilibration between sample and room air in the dead space in sampling syringes.[8] Immediate debubbling does not totally diminish the room-air, dead-space effect.[8] It has been hypothesized that greater oxygen gradients may result in larger P_{aO_2}-estimation errors.[8] A small but significant overestimation of P_{aO_2} was also observed in the present study, but only in the 0.2-mL sample. Larger sample volumes were not significantly affected. Perhaps the ratio of dead space to sample volume influences the rate and magnitude of equilibration.

Estimates of pH, P_{aCO_2}, potassium, and THb were unaffected by sample size, in agreement with the results of other studies.[6-8,15] Lithium heparin concentrations as high as 250 IU/mL appeared to cause no variation in these analyte values when measured on MBGES.

Previous studies have shown that small sample size and high concentrations of anticoagulant affect precision and accuracy in blood gas and electrolyte measurements.[6,11-13] Those results led us to establish the hypothesis that the same effects would also manifest themselves in simultaneous blood gas/electrolyte measurements on MBGES. We decided that it was not necessary to sample a larger and more diverse human population to ascertain whether the same errors in precision and accuracy would occur. Multiple samples from one healthy subject in a stable environment provided the control blood sample. The errors in precision observed in this study may have resulted from wide fluctuations in the subject's circulating blood electrolyte levels, although this is unlikely because the subject's post-study serum electrolytes were unchanged from pre-study values.

Our results reconfirm much of what was already known about preanalytic errors in each of the two separate measuring (blood gas and electrolyte) techniques. However, it must be emphasized that a MBGES combines these two technologies in one instrument. Even though this is an attractive and increasingly popular practice, it is only an assumption, as far as sample size and heparin concentration are concerned, that this is acceptable for accurate and precise results. Emphasis on the abil-

ity to measure both blood gases and electrolytes with a microsample (0.2-0.8 mL) of whole blood is lauded by the manufacturers. However, as our results show, microsample volumes may be appropriate for blood gas analysis but are not applicable for sodium and ionized calcium estimations. Clinicians need to be aware of the drawbacks of the marriage of these two technologies.

In many areas of clinical practice, it is appropriate to use small sample volumes. These may include sampling techniques for newborn and young infants. The widespread availability of bedside electrolyte and blood gas analysis may result in more frequent sampling, leading to a desire to use small sample volumes. We have demonstrated that errors in both blood gas and electrolyte analysis occur through sampling technique, presumably because of interference with anticoagulants or contamination with room air.

Conclusions

We suggest that the errors in estimation of P_{aO_2}, sodium, and ionized calcium that we have observed should lead to caution in the interpretation of the results obtained using a MBGES when high concentrations of heparin or very small sample volumes are being used. When using standard sampling syringes containing 50-IU heparin pledgets, one should use a minimum sampling volume of 0.6 mL to obtain accurate and precise measurements.

ACKNOWLEDGMENTS

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PRODUCT SOURCES

Blood Gas/Electrolyte Analyzer:
Multichannel Blood Gas/Electrolyte System, Corning 288, Medfield MA
Aspirator Kits:
MQ601W, Marquest Medical, Englewood CO
Calibration Controls:
Certain + Level 1, 2, 3, Ciba-Corning Diagnostics, Medfield MA
Statistical Software:
Statgraphics, Version 5.0, Statistical Graphics Corp, Rockville MD

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Bronchoscope Damage and Repair Costs: Results of a Regional Postal Survey

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Flexible fiberoptic bronchoscopy is a commonly performed procedure for which the indications, technical aspects, and potential patient complications have been well described. However, limited information is available regarding damage to the instrument itself. In order to better describe the types and causes of bronchoscope damage, repair costs, and time out of service, we performed a postal survey of hospital bronchoscopy laboratories in Alabama, Mississippi, and Louisiana. We received 43 completed surveys from laboratories that perform an average of 233 bronchoscopies per year. The respondents reported 103 episodes of bronchoscope damage, the majority of which consisted of damage to the bronchoscope cover, broken fiber bundles, malfunction of the bending apparatus, and suction channel damage. The respondents attributed 62% of all the damage to one of the three following categories: unknown, improper handling, and damage caused by biopsy forceps, brushes, or needles. Of the 103 episodes of bronchoscope damage, 66 (64%) were judged to be preventable, 13.6% not preventable, and 17.5% to be indeterminant. The average time out of service (mean, SD) for each damaged bronchoscope was 3.5 (3.9) weeks, and the average repair cost per episode of bronchoscope damage was $2,726.13 ($1,391.21). At least 19 episodes of bronchoscope damage occurred during cleaning and disinfecting procedures. We conclude that the majority of bronchoscope damage and repair costs should be potentially preventable and suggest that a program to familiarize all personnel handling bronchoscopes with proper maintenance and handling procedures should decrease the risk of bronchoscope damage. (Respir Care 1992;37:1256-1259.)

Introduction

Since its introduction into the United States in the early 1970s, flexible fiberoptic bronchoscopy has become a procedure commonly performed by pulmonary and critical care physicians for a variety of diagnostic and therapeutic purposes. Several published studies have described the technical aspects of the procedure, including indications and contraindications, preoperative medications, diagnostic yields of various bronchoscopic procedures, and patient complications.[1-7] Much less information has been available regarding maintenance, damage, and repair costs for the instruments themselves.[8,9] After two episodes of bronchoscope damage that we felt were potentially avoidable had occurred in our laboratory, we wished to compare our experience with that of other laboratories. Except for a recently published report from a single institution describing their own experiences with bronchoscope damage,[9] we could find remarkably little published literature describing types of damage. Therefore, we prepared and mailed a questionnaire requesting information about bronchoscope damage and repair costs to hospital bronchoscopy la-

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Presented in part in abstract form at the American Thoracic Society International Conference, May 18, 1992, in Miami Beach, Florida.

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boratories in our geographic area, and here report the results of that postal survey.

Methods

We mailed questionnaires to 180 hospitals of 100 or more beds in Alabama, Mississippi, and Louisiana. The questionnaires were addressed to the Respiratory Care Department, but in a cover letter included with the questionnaire we requested that the survey be forwarded to the appropriate department head if flexible bronchoscopies were routinely performed in a department other than the Respiratory Care Department. Approximately 8 weeks after the initial mailing, a reminder was mailed to all hospitals. The survey instrument was a 3-page questionnaire containing 20 questions regarding demographics (such as hospital size, number of procedures performed, and personnel assisting bronchoscopists) and requesting specific information about bronchoscope damage and repair costs. We requested detailed information about each episode of bronchoscope damage, including (1) type of damage to the bronchoscope; (2) cause of the damage; (3) whether the damage was judged preventable, not preventable, or indeterminant; (4) how long the bronchoscope was out of service; and (5) the cost of the repair. Because few of the respondents specified the date for each episode of damage, we were unable to calculate episodes of damage per year. In addition, some questions were not completed by all respondents and, consequently, the total number of responses varies with the different questions and this is so indicated in the results section.

Results

A total of 46 questionnaires was returned, 3 of which were from hospitals where flexible bronchoscopy was not performed; therefore, our results include responses from 43 hospital bronchoscopy laboratories. For the 43 responding hospitals, the bed capacity [mean (SD)] was 308 (181) with a range of 100-863 beds. The responding laboratories reported owning 127 bronchoscopes. The number of bronchoscopies per year [mean (SD)] was 233 (182), with a range of 12-950 bronchoscopies per year. Pulmonologists or pulmonary fellows performed 87.5% of all flexible bronchoscopies and the route of bronchoscopy was reported to be as follows: 82.9% transnasal, 11.4% via endotracheal or tracheostomy tube, and 5.7% transoral. In response to the question "Who assists the bronchoscopist?," 32 laboratories reported respiratory therapists assisted, 16 reported a nurse (RN or LPN) assisted, and 10 reported "other." Because several laboratories listed more than one category of bronchoscopy assistant, the total is greater than the number of respondents.

There were 103 episodes of bronchoscope damage reported by 39 responding laboratories. Three respondents specifically stated that they had had no bronchoscope damage, and one did not respond to this question. When categorized by type of damage, damage to the bronchoscope cover and broken fiber bundles accounted for almost 75% of all the damage reported (Table 1).

Table 1. Types of Damage Described for 103 Episodes of Bronchoscope Damage

Type of Damage	Number of Episodes	% of Total
Damage to covering (includes tears, leaks, ruptures)	49	47.5
Broken fibers	27	26.2
Malfunction of bending apparatus	11	10.8
Channel damage	9	8.7
Miscellaneous*	7	6.7

*See text for details of damages included in miscellaneous.

Malfunction of the bending apparatus and suction channel damage were reported less commonly. The types of damage included in the category "other" include bronchoscope meltdown secondary to steam autoclaving (2 episodes), tip burned by laser (1), crushed when drawer closed on bronchoscope (1), discolored fibers (1), dislocated lens (1), and clouding of lens (1). When the causes of damage were categorized (Table 2) the respondents attributed 64 of the episodes of damage (representing 62% of all damage) to one of the following 3 categories: unknown, improper or rough handling, and

damage caused by biopsy forceps, brush, or needle. Causes of damage included under "other" are steam autoclaved (2 episodes), cotton swab broken off in channel (1), excessive pressure during leak testing (1), normal wear and tear (2), manufacturer's defect (1), soaked too long in disinfectant solution (1), and no cause of damage specified (3).

Table 2. Causes of Damage for 103 Episodes of Bronchoscope Damage

Cause of Damage	Number of Episodes	% of Total
Damage by insertion through ET* tube or tracheostomy tube	4	3.9
Bite damage by patient	10	9.7
Unknown	25	24.3
ETO without proper venting	10	9.7
Improper/rough handling	18	17.5
Biopsy forceps/brush/needle	21	20.4
Damaged by laser	4	3.9
Miscellaneous†	11	10.7

* ET = endotracheal; ETO = ethylene oxide sterilization.
† See text for causes in this category.

The respondents judged 66 of the 103 episodes of bronchoscope damage (64%) to be potentially preventable, 14 episodes (13.6%) not preventable, 18 episodes (17.5%) to be indeterminant, and no response to this question was given for 5 (4.8%) of the episodes. Based on 81 responses, the time out of service [mean (SD)] for each damaged bronchoscope averaged 3.5 (3.9) weeks. Based on 83 responses, the average repair cost [mean (SD)] per episode of bronchoscope damage was $2,726.13 ($1,391.21), with a range from no charge (manufacturer's defect) to $6,000. Of the 103 episodes of bronchoscope damage, the respondents reported that 19 occurred during cleaning and disinfection or sterilization of the bronchoscope (Table 3). Based on responses from 39 hospitals, 61.3% of all personnel handling the bronchoscopes were "familiar with or had read the instruction manual that accompanies each bronchoscope."

Table 3. Bronchoscope Damage Occurring during Cleaning or Disinfecting/Sterilizing of the Instrument

Damage	Number of Episodes	% of Total
ETO* without proper venting	10	52.6
Damaged by cleaning brush	3	15.8
Accidentally steam autoclaved	2	10.5
Rough handling	2	10.5
Soaked too long in disinfectant	1	5.3
Leak test not performed and disinfectant leaked inside cover	1	5.3

*ETO = ethylene oxide sterilization.

Discussion

The results of this survey indicate that the majority of episodes of bronchoscope damage and their attendant repair costs should be potentially preventable. Although the accuracy of the results that we present is dependent on the information provided on our returned survey forms, both the types of damage and costs of repair we report are remarkably similar to the published experiences of a single large institution performing a large number of flexible bronchoscopies.[9] For example, the average repair costs per episode of damage at the Cleveland Clinic reported by Mehta et al[9] was $2,139.60 compared to $2,726.13 reported in this study. Likewise, our survey results are similar to their experience in that the majority of episodes of bronchoscope damage were judged to be potentially preventable. Although the determination of "potentially preventable damage" is a subjective decision, clearly such causes of damage as improper handling, ethylene oxide sterilization without proper venting, and steam autoclaving are without question preventable. Another perspective of the cost of potentially preventable damage can be seen if the average repair cost reported in this study (based on the 83 responses to this question) is extrapolated to

all 103 episodes of bronchoscope damage. The total repair cost then for all 103 damage episodes would be $280,791.39. If 64% of these episodes were preventable, then as much as $179,706.49 may have been spent on bronchoscope repairs that could have been avoided.

Our survey did not contain information that would allow us to determine how many of these episodes of bronchoscope damage may have been caused by carelessness versus simple lack of knowledge of proper handling techniques. Nevertheless, respondents indicated that only 61% of personnel handling the bronchoscope were familiar with the instruction manual that accompanies each new bronchoscope. Mehta et al, in their own internal survey, found that only 11% of personnel involved with bronchoscopic procedures had familiarized themselves with the instruction manual.[9] We agree with these authors that the instruction manual[10] is quite explicit and provides clear information regarding proper handling procedures, including cleaning and disinfection/sterilization procedures. Based on our experience and results of this survey, our own laboratory has established a policy that requires all new personnel (including new pulmonary fellows) to read and understand the bronchoscope instruction manual. In addition, personnel who will be cleaning and disinfecting the bronchoscope will be closely supervised until they have demonstrated proficiency in these techniques. Because the respondents indicated that the majority of individuals assisting bronchoscopists were respiratory therapists, we encourage respiratory therapy schools that have not already done so to include instructions and practical experience on handling of flexible bronchoscopes in their curricula.

The results of this survey may not be applicable to bronchoscopes that are used by anesthesiologists and surgeons in the operating room setting, which are cleaned and maintained by operating room personnel. Although respondents did not indicate the location of bronchoscopic procedures performed at their institution, the fact that 87.5% of all bronchoscopies were performed by pulmonologists and pulmonary fellows and that most of the bronchoscopy assistants were respiratory therapists suggests that operating room bronchoscopies were not well represented in this survey.

In summary, results of this study support limited previous data indicating that the majority of episodes of bronchoscope damage and their attendant repair costs should be preventable. Although it was not addressed by our study, we speculate that more supervised practice and formal and informal instruction for personnel in proper handling techniques would likely reduce bronchoscope damage and repair cost.

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Evaluation of a Closed-System, Directional-Tip Suction Catheter

Terry P Hart RRT and C Kees Mahutte MD PhD

INTRODUCTION: It is difficult to successfully suction the left bronchial tree. We evaluated the success rate of left bronchial cannulation with a new closed-suction directional-tip catheter (Trach Care directional-tip catheter, TCDT, Ballard Medical Products, Midvale UT). Success rates were compared in patients with endotracheal and tracheostomy tubes. We also studied the effects on success rate of (1) the distance of the endotracheal tube from the carina, (2) the tube's bevel orientation, and (3) the tube's position in the patient's mouth. METHOD: At the time of the routine daily chest radiograph, 75 attempts at left bronchial cannulation were made in 45 patients. With the head maintained in a midline position, the TCDT catheter was advanced with the radiopaque blue line in the 1 o'clock position. The radiograph was evaluated for correct placement of the TCDT catheter. RESULTS: Due to lung pathology and x-ray technique, catheter placement could not be interpreted in 17% of the radiographs. In the remainder, overall success rate was 71% (79% with tracheostomy tubes and 67% with endotracheal tubes, not significantly different, with $p > 0.3$). Tube distance from the carina and bevel orientation did not significantly affect success rates. Success rates for tubes located in the left and central positions of the patient's mouth were significantly better ($p < 0.002$ and $p < 0.03$, respectively) than for tubes located on the right side of the patient's mouth. With the endotracheal tube on the left side of the patient's mouth, the success rate was 89%. CONCLUSION: We conclude that the TCDT catheter successfully combines the features of a closed-suction system with those of a directional-tip catheter that allows selective bronchial cannulation, a large percentage of the time. (Respir Care 1992;37:1260-1265.)

Introduction

Critically ill patients—particularly those who are intubated—frequently are unable to adequately clear their secretions and therefore require suctioning. Both secretions and atelectasis occur more commonly in the left lower lobe.[1,2] Although suctioning of the right bronchial tree is easily accomplished, it is well known that is is more difficult to successfully suction the left bronchial tree because the left main-stem bronchus is narrower than the right and makes a sharper angle with the trachea.[3] Thus the suction catheter tends to enter the wider right bronchus. Studies have shown that if a curved-tip catheter is used, the success rate of entering the left main-stem bronchus is increased.[3-8] Reported success rates vary from 26%[5] to 97%[7] for endotracheal tubes and are typically better with tracheostomy tube suctioning.[3,5,8] The addition of a guideline to facilitate positioning and to improve torque control has also been shown to favorably affect success rates.[6-8] Head positioning has not been shown to have consistent effects.[3,4,8] Recently, curved-tip catheters have been used to successfully treat refractory atelectasis of middle and lower lobes.[9]

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Various closed-suction-system catheters are now available. These catheters are more expensive but have a number of advantages.[10] The same catheter can be used on a patient for 24 hours, decreasing the work time associated with suctioning. Because a plastic sheet envelops the catheter, the dissemination of secretions is reduced during suctioning. Even though the incidence of colonization is reported to be increased with the closed-suction method compared to the open-suction method, the incidence of nosocomial pneumonia is not increased, and, in fact, the closed-suction method may be associated with a decreased mortality.[11] Finally with these catheters, PEEP can be maintained and consequently deterioration in oxygenation can be ameliorated during suctioning.[10]

Recently a closed-suction curved-tip catheter with a radiopaque-blue line marker (Fig. 1) has become available. As far as we are aware, the success rate of left bronchial cannulation with this Trach Care directional-tip (TCDT) catheter* has not yet been reported. It was our purpose to assess the success rate of left bronchial cannulation with this TCDT catheter in ICU patients with both endotracheal and tracheostomy tubes. We also studied the effects on success rate of (1) the distance of the endotracheal tube from the carina, (2) the tube's bevel orientation, and (3) the tube's position in the patient's mouth.

Methods

All intubated or tracheostomized patients who required endotracheal suctioning for clinical reasons were candidates for the study. Patients were typical of our medical ICU population and included patients with acute respiratory failure due to pneumonia, exacerbations of COPD, sepsis, or cardiac failure. The need for informed consent was waived by the hospital's Human Experimentation Committee. Cannulation of the left bronchial tree was attempted (as described below) at the time the routine daily radiograph was taken. All attempts at cannulation were made by the same author-investigator (TPH). A patient was eligible for re-study in a random manner on another subsequent day, irrespective of success or failure of the first attempt, if he still required suctioning, if the primary author (TPH) was available to do the suctioning, and if a radiograph had been scheduled.

*Suppliers are identified in the Product Sources section at the end of the text.

Fig. 1. Trach Care directional-tip suction catheter. Note the plastic sheet around the 43-cm long catheter.

Prior to the TCDT catheter insertion, the inspired oxygen concentration on the ventilator was set at 100%. With the head maintained in the midline position, the catheter was advanced with the radiopaque line in the 1 o'clock position (as suggested by the manufacturer for successful left bronchial suctioning). Once the catheter was thought to be in the proper position, the radiograph was taken. After the radiograph had been taken, the patient was suctioned as clinically indicated. Cardiac rhythm and pulse oximetry were routinely monitored during the procedure. If either an important rhythm abnormality or substantial arterial desaturation occurred, suctioning would be aborted (none occurred during this study). The chest radiograph was subsequently evaluated by the primary author-investigator (TPH) for catheter placement in the left bronchial tree (Fig. 2). If there was any doubt about catheter position or the tip could not be visualized, the opinion of the ICU radiologist was elicited. Similarly, the distance of the tip of the endotracheal tube from the carina was estimated from the radiograph. Tubes were categorized according to their placement above the carina (3 to < 4, 4 to < 5, 5 to < 6, 6 to < 7, and 7 to < 8 cm). The type of artificial airway, position of the endotracheal tube in the mouth, and bevel orientation were also recorded. The endotracheal tube was noted to be located centrally or on the right or left side of the patient's mouth. The bevel orientation was deter-

mined from the placement of the lettering on the endotracheal tube. The brand of endotracheal tubes that we use (Portex Blue Line) has a standard design with the lettering on the same side as the beveled opening at the tip of the tube. The bevel faces toward the patient's left when the concave section of the tube is facing forward.

We calculated the rate of successful catheter placement in the left bronchial tree from the radiographs. The effects of (1) the type of artificial airway, (2) tube position in the trachea, (3) bevel orientation, and (4) tube position in the patient's mouth on success rates were analyzed via a computer program with the χ^2 test[12] and Goodman interaction.[13] The Goodman interaction is basically an analysis of all possible combinations of two-by-two tables. A p value < 0.05 was considered significant.

Results

We made 75 attempts to cannulate the left bronchial tree in 49 patients. In 13 of these attempts, the catheter position could not be reliably determined due to lung pathology and/or radiographic technique. The overall success rate for left bronchial cannulation in the remaining 62 attempts was 71%. The success rate (Fig. 3) for oral endotracheal tubes was 66% (n = 41), tracheostomy tubes 79% (n = 19), and nasal endotracheal tubes 100% (n = 2). None of these results was statistically different ($p > 0.3$). In 18 patients in whom two or more attempts at cannulation were made, the success rate of the different attempts was not significantly different ($p > 0.1$). In these patients the success rate was 60% on the first attempt, 69% on the second attempt, and 75% on the third attempt.

Fig. 2. Chest radiograph showing successful left bronchial tree cannulation.

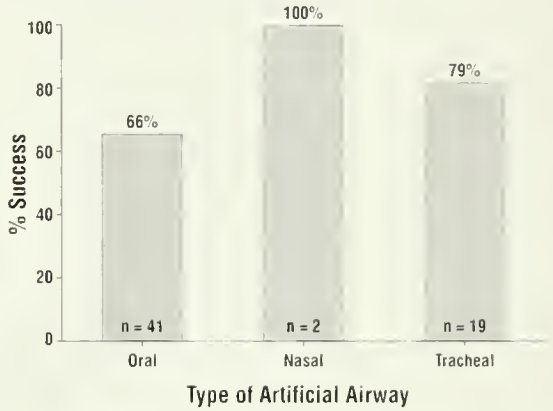

Fig. 3. Success rates of different types of artificial airways. None of the results was significantly different ($p > 0.3$).

The success rates for the tube placement positions relative to the carina are shown in Figure 4. Success rates were independent of tube distance above the carina ($p < 0.1$). The effect of bevel orientation is shown in Figure 5. As expected, most bevels pointed to the left (n = 39) consistent with the natural tube curvature. However, some tubes (n = 4) had been rotated by the therapist, nurse, or patient. Bevel orientation also did not significantly affect the success rate of left bronchial cannulation ($p = 0.44$).

The effect of oral endotracheal tube position in the patient's mouth on success rate is shown in Figure 6. Of the 41 oral endotracheal tubes studied, 18 were located on the left side, 14 were on the right side, and 9 were centrally located in the patient's mouth. Success rates for tubes located on the left or centrally were significantly better when compared

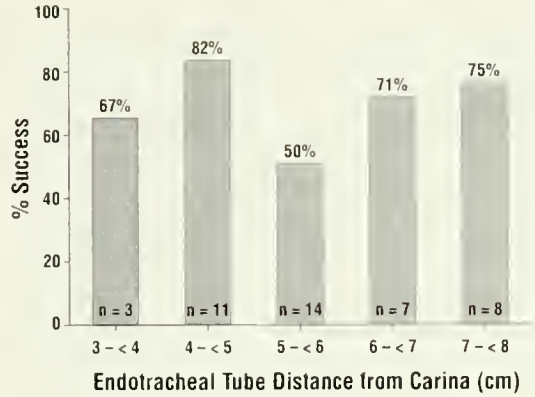

Fig. 4. Success rate as a function of the distance of the endotracheal tube tip from the carina. None of the results was significantly different ($p > 0.1$).

to those located on the right ($p < 0.002$ and $p < 0.03$, respectively). No statistically significant differences ($p = 0.45$) were found for tubes located on the left or centrally in the patient's mouth.

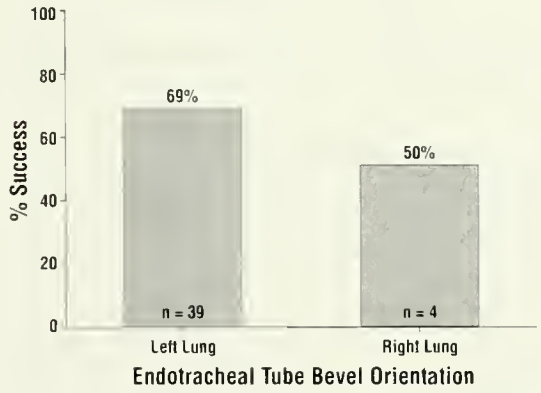

Fig. 5. Success rate as a function of the endotracheal tube bevel orientation. None of the results was significantly different ($p = 0.44$).

Discussion

In this study in medical ICU patients, we obtained an overall success rate of 71% for left bronchial cannulation with the TCDT catheter. The overall success rate for endotracheal (oral and nasal) tubes was 67%. Although this success rate is worse than reported in some studies,[6,7] it is comparable[8] or better[3-5] than rates reported in other studies with directional-tip catheters. Consistent with results reported by others,[3,5,8] we found the success rate to be higher (although not to a statistically significant extent) for tracheostomy tubes compared to endotracheal tubes. Some studies have reported improved results with the patient's head turned to the right,[3] to the left,[8] or kept midline.[4] Because of these conflicting results, we maintained the head in a neutral, midline position and did not study the effect of this variable. We also found in this group of patients that the success rates were not significantly affected by the distance of the endotracheal tip from the carina. When the endotracheal tube tip is less than 3 cm above the carina, it becomes difficult to cannulate the left bronchus. One might therefore have hypothesized that tube distance would have affected the success rates. We did not find this to be true. However, it is to be noted that it was difficult to make an accurate estimate of this distance because the radiographic equipment was all portable. Inaccuracy in this measurement was anticipated and might have affected the results. Similarly, success rates were not significantly affected by bevel orientation. One would expect bevel orientation to be important if the tip of the tube is close to the carina. Because our tubes were mostly located well above the carina (Fig. 4), this result is not surprising.

The success rate was significantly influenced by the position of the oral endotracheal tube in the patient's mouth. Tubes located centrally or on the left side resulted in higher success rates than tubes located on the right (Fig. 6). We were unaware of any similar data in the literature and, therefore, were surprised at this finding. To explain our find-

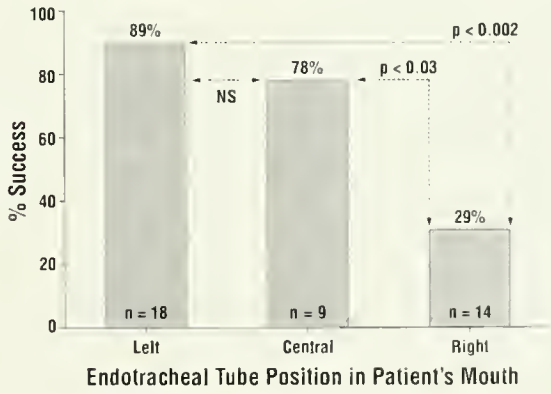

Fig. 6. Success rate as a function of the tube's position in the patient's mouth. Left was significantly better than right ($p < 0.002$) and central was significantly better than right ($p < 0.03$). NS = left and central positions were not significantly different.

ing we hypothesized that the additional curvature at the mouth enhanced the torque control for more successful left bronchial cannulation. To confirm this speculation we inserted an endotracheal tube in a bronchoscopy teaching manikin. With the tip of the endotracheal tube held in a fixed position and the TCDT catheter fully inserted, we manipulated the endotracheal tube position at the mouth from left to right. It was very apparent that, with the endotracheal tube in the left side of the mouth, the tip of the TCDT catheter pointed more directly toward the left bronchus. We are therefore confident of the validity of our results and hence recommend that in order to obtain the highest success rate for left bronchial cannulation, the oral endotracheal tube be tied on the left side of the patient's mouth.

As we have mentioned, there is some evidence that secretions accumulate more readily in the left lower lobe,[1] and after coronary artery bypass surgery, atelectasis also occurs more commonly in the left lower lobe.[2] It stands to reason that accumulation of secretions and atelectasis with a concomitant deterioration in blood gas values may be preventable with effective suctioning. However, it is a sine qua non that prior successful cannulation of the left lower lobe has to occur for suctioning of that lobe to be effective. Whereas numerous studies have assessed left lower lobe cannulation,[3-8] we are not aware of any study that specifically has assessed the clinical efficacy of left bronchial suctioning. In view of the additional expense associated with curved-tip catheters, we recommend that they be used in patients in whom left-side disease is either present (secretions, atelectasis, pneumonia) or anticipated (such as following coronary artery bypass surgery). Recently, Kubota et al[9] reported the successful treatment of refractory atelectasis of middle and lower lobes in 9 patients with the use of curved-tip catheters. They suggest that selective bronchial suctioning with these curved-tip catheters is the treatment of choice for refractory atelectasis when respiratory therapy is ineffective or a bronchoscopy is not available. It would clearly be desirable to have more information on the clinical efficacy of left-side and selective bronchial suctioning with curved-tip catheters.

The TCDT catheter has a number of advantages demonstrated by others[10,11] to which we have already alluded—the ability to maintain PEEP, the control of secretion dispersal, reduction in suctioning time, and possible reduction in pneumonia. A disadvantage of the catheter is its cost, which is substantially more than regular single-use catheters. The cost of the TCDT catheter is slightly higher than that of the simple closed-suction catheter. Although we feel that the use of this catheter in patients requiring left-side bronchial suctioning is justified, the results of a formal cost-benefit analysis would be of considerable interest. In addition, studies on the clinical efficacy of selective bronchial suctioning are desirable.

In conclusion, the TCDT catheter combines the features of a closed-suction catheter with the ability to selectively cannulate the left bronchial tree. We achieved the highest success rates (89%) for successful left bronchial cannulation with the endotracheal tube in the left side of the patient's mouth.

ACKNOWLEDGMENTS

We wish to thank Priscilla Chin and Catherine Sassoon MD for their assistance.

PRODUCT SOURCES

Suction Catheters:
Trach Care directional-tip catheter, Ballard Medical Products, Midvale UT

Endotracheal Tubes:
Blue Line tracheal tube, Portex, Keene NH

Statistical Software:
StatPac, Version 6.0, Walonik Associates, Minneapolis MN

Intubation Manikin:
Broncho Bob, Armstrong Industries Inc, Northbrook IL

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PFT Corner #46— Results of Exercise Testing in a 33-Year-Old Man

Rick Kelley BS RPFT

A 33-year-old man was referred to the pulmonary function laboratory from the pulmonary clinic for a cardiopulmonary exercise study because of his complaint of increasing dyspnea on exertion. He had worked as a mail carrier for 9 years and was a 30-pack-year smoker. Physical examination was normal except for mild obesity. Chest radiographs showed bilateral pleural thickening in the mid-lung zones. The resting electrocardiogram was normal. Results of pulmonary function testing and blood gas analysis are shown in Table 1 and pre-exercise and post-exercise flow-volume, and volume-time curves, and maximum voluntary ventilation (MVV) tracing are shown in Figures 1 and 2.

Questions

1. How do you interpret the results of pre- and post-exercise pulmonary function testing and blood-gas analysis?
2. How do you interpret the exercise test results?
3. If limitation is present, how do you distinguish between a cardiac and pulmonary cause? What is the significance of the negative breathing reserve and what accounts for such results?

Mr Kelley is a technologist in the Pulmonary Function Laboratory, University Hospital and Clinics, Madison, Wisconsin.

Table 1. Results of Testing of a 33-Year-Old Man Complaining of Increasing Dyspnea on Exertion

Pulmonary Function

Variable	Pre-Exercise (% predicted)	Post-Exercise
FVC (L)*	3.59 (68)	3.63
FEV_1 (L)	2.19 (53)	2.08
MVV (L/min)	82.4 (47)	—
D_{LCO} (mL · torr · min^{-1})	31.4 (91)	—

Arterial Blood Gas Analysis

Variable	Pre-Exercise	
P_{aO_2} (torr)	81	—
Oxygen saturation (%)	95	—
P_{aCO_2} (torr)	39	—
pH	7.41	—
Total hemoglobin (g/dL)	14.4	—
COHb (%)	1.1	—

Exercise Test

Variable	Predicted	Observed
Maximum $\dot{V}_{O_2}$ (mL/min STPD)	3596	2785
$\dot{V}_{O_2}$ at anaerobic threshold (%)	40	31
Maximum heart rate (beats/min)	187	128
Cardiac reserve (beats/min)		59
Maximum $\dot{V}_E$ (L/min BTPS)	88	101
Breathing reserve (L)	> 15	–18 (based on measured MVV) –12 (based on calculated MVV)
Maximum work rate (watts)	283	174

*Technologist reported that patient was cooperative and appeared to exert maximum effort.

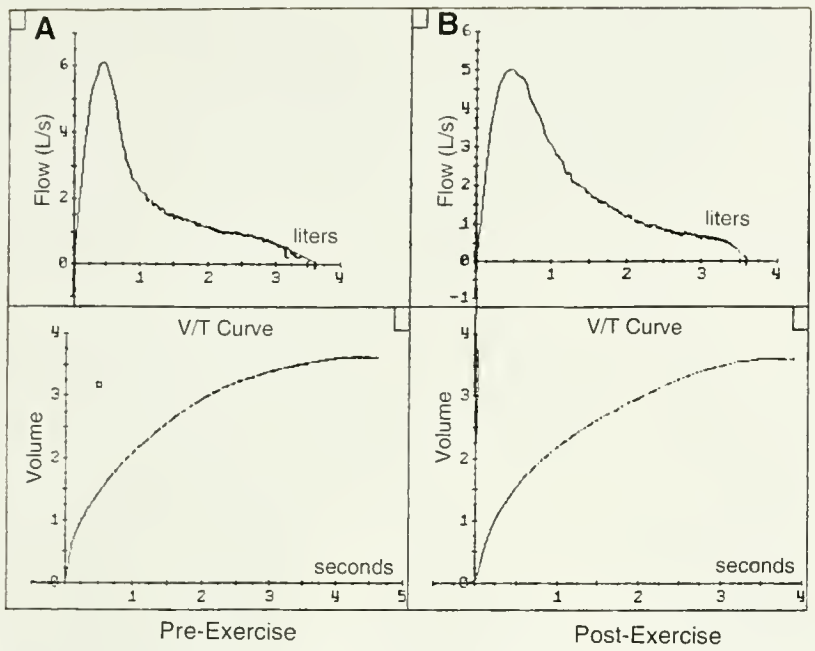

Fig. 1. A. Flow-volume and volume-time curves of a 33-year-old man complaining of increasing dyspnea on exertion, recorded before exercise. B. Flow-volume and volume-time curves recorded 5 minutes following completion of a symptom-limited exercise test.

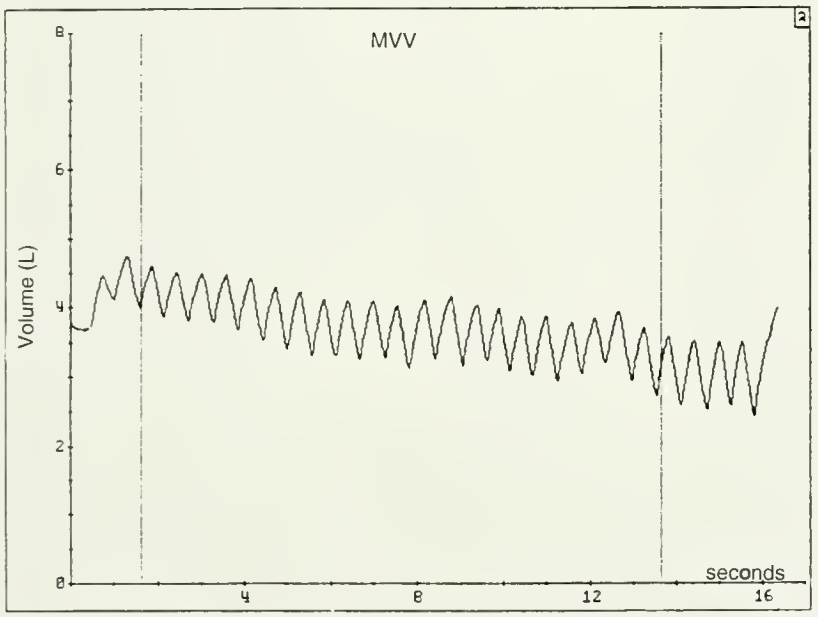

Fig. 2. Tracing made during maximal voluntary ventilation (MVV) maneuver by 33-year-old man complaining of increasing dyspnea on exertion.

Answers and Discussion on Next Page

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Answers and Discussion

Test Interpretation

Pulmonary Function & Blood Gas Analysis: Spirometry shows an obstructive ventilatory defect that is essentially unchanged with exercise. Diffusing capacity and arterial blood gas results are within normal ranges.

Exercise Testing: Exercise data reveal that the subject has an abnormally low exercise tolerance. This is indicated by the observed maximum work rate of only 61% of predicted, and a maximum $\dot{V}_{O_2}$ of 77%. The poor exercise performance is due to pulmonary limitations caused by airflow obstruction. This is verified by the negative breathing reserve and the increased cardiac reserve.

To interpret a cardiopulmonary exercise test, the breathing reserve (BR) must be calculated. Breathing reserve is defined as the unused portion of the MVV, calculated as:

$$BR = MVV - \dot{V}_{Emax}; \text{ or}$$
$$(FEV_1 \times 40) - \dot{V}_{Emax},$$

where $\dot{V}_{Emax}$ = maximum exhaled minute volume.

Because MVV is highly effort dependent, the value may be estimated from the FEV_1. However, this method for estimating the MVV may underestimate the actual volume in subjects with restrictive disease and overestimate it in subjects with obstructive disease.[1]

Negative Breathing Reserve

If MVV value is truly the maximum voluntary ventilation a subject can achieve, then it would seem that by definition the BR could never be a negative value. In this subject, however, the BR is a negative 18 L, or a negative 13 L if estimated from the FEV_1. Negative BR can be due to three possible reasons. (1) The MVV maneuver is very much an effort-dependent test. The BR can be negative if the MVV value is taken from a submaximal effort. (2) Some bronchodilation can occur with exercise, which can increase the subject's maximum ventilation. (3) Many subjects with obstructive defects breathe at a higher lung volume during exercise than at rest. This maneuver allows them to achieve higher flowrates.[2,3]

After review of the spirogram and MVV tracings, it appears that the technologist was correct in assuming that the subject provided a maximum effort on spirometry and MVV maneuvers (Figs. 1 & 2). If the subject gives a poor effort, then the $\dot{V}_{Emax}$ will be underestimated and a negative breathing reserve can result. Let us assume that this was a maximum effort and that the negative BR cannot be explained by the first possibility.

The post-exercise spirometry values indicate that there were no significant changes in flowrates after the exercise. However, in subjects with airway obstruction at rest, a small degree of bronchodilation may occur with exercise. This dilation may be due to increased sympathetic drive and thus increased early $\dot{V}_E$ values. This could explain increased $\dot{V}_{Emax}$ in some subjects.[4]

The third choice seems to be most appropriate in this subject. The phenomenon of increased flowrates during exercise in obstructive subjects has been described in a number of papers. Grimby and Stiksa[2] compared flow-volume curves at rest and during exercise in 12 patients and documented flow-volume curves during exercise that exceeded the flows achieved at rest. Hyatt and colleagues[3] demonstrated that subjects with obstructive lung disease will breathe at a higher lung volume by increasing their pleural pressures. During exercise, this higher lung volume allows the subject to continually breathe on a portion of the flow-volume loop that allows maximum ventilation. However, this also results in an increased work of breathing and may, therefore, be a limiting factor of exercise tolerance.

It has been suggested that in order to document ventilation as a limiting factor in exercise testing, flow-volume loops should be performed during exercise and at rest.[3,5] Then using techniques that adjust the loops for change in lung volume, the exercise loop can be superimposed on the resting loop. If during exercise the subject reaches the flowrates achieved at rest, then the subject can be said to have a pulmonary limitation to exercise.

With computerized exercise equipment, it is not easy to perform and record flow-volume loops during exercise. Therefore, the calculated breathing reserve is most commonly reported. Laboratory personnel must be aware of the limitations, and realize that in the subject with obstructive pulmonary disease a negative breathing reserve is common.

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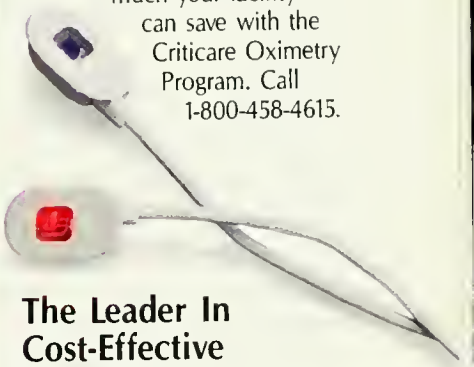

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'Applied Physiology' for Primary School Children in 1898*

Chapter VI—TOBACCO

Harmful eating—Men often eat for the fun of eating, and sometimes they eat harmful things. They chew tobacco and drink strong drinks, because they like their taste, just as a child eats candy.

Tobacco—Men have always drunk strong drink. Within the last four hundred years, men have learned another way to please a wrong taste. When Columbus discovered America, the Indians were using tobacco. They taught the Spaniards how to smoke it, and since then almost the whole world has used it.

Tobacco is the leaf of a tall plant. It needs a better soil than any other crop. It takes the richness from the ground, and spoils it for other crops.

Nicotine—About 1/30 of each tobacco leaf is a strong poison. This poison is called *nicotine*. A drop or two of it, or as much of it as is in a strong cigar, will kill a man. It gives the tobacco its smell and taste. Men use tobacco for the sake of a poison.

Why men use tobacco—Men give queer reasons for using tobacco. One smokes for its company, another because he is with company. One smokes to make his brain think better, and another to keep himself from thinking. Some use tobacco to help digest their food, and others use it to keep themselves from eating too much. Boys smoke to make themselves look like men. The real reason for using tobacco is that men learn to like its taste, and do not care if it harms them.

Spitting—Tobacco in any form makes the saliva flow. Men do not dare swallow it, for it makes them sick. So they spit it out. No one likes to see this. It is a dirty and filthy habit. Besides, the saliva is lost, and cannot help digest food.

Tobacco stains the teeth brown. You can always tell a tobacco chewer by his teeth. His breath will smell of tobacco, and even his clothes are offensive to the nose.

Tobacco lessens strength—Tobacco always makes a person sick at the stomach, at first. After a while, he becomes used to it, and an ordinary chew or smoke does not make him sick. But a large chew or smoke will always make him sick again. When a person is sick from tobacco he is very weak. Even if he is not sick, the tobacco poisons his muscles and makes his strength less. When a man trains for a hard race he never uses tobacco.

Tobacco hinders digestion—Tobacco and its smoke both have a burning taste. This makes the throat sore, and causes a cough. Tobacco does not help the stomach to digest food. Smokers and chewers often have headaches and coated tongues. These are signs of poor digestion.

Effect upon the young—Tobacco is more harmful to boys than to men. If boys smoke they cannot run fast or long. They cannot work hard with their brains or hands. They do not grow fast, and are liable to have weak hearts.

Tobacco harms others—Many persons do not like the smell of tobacco, and no one likes the spit. No one should use it in the presence of others. The tobacco user's pleasure should not spoil the comfort and happiness of others.

*These extracts are from the book "Applied Physiology, Including the Effects of Alcohol and Narcotics, Primary Grade," by Frank Overton AM MD, published in 1898 by American Book Company. Pat Brougher RRT, of Dallas, Texas, found the book in a secondhand store in Fort Smith, Arkansas.

Snuff—Powdered tobacco is called snuff. Snuff causes sneezing. No one should harm the nose and the whole body for the pleasure of a sneeze. Years ago snuff was used much more than it is now.

Chewing—Chewing tobacco is the most poisonous way of using it, for it keeps most of the nicotine in the mouth. Chewing will make any one very sick, unless he spits out all the saliva.

Smoking—Men smoke pipes, cigars, and cigarettes. The smoke has nicotine, and is poisonous. Pipe stems get dirty and full of nicotine. After a while they smell bad and are very poisonous. An old smoker's pipe will make a young smoker sick.

Cigarettes—Cigars are not so poisonous as a pipe, for more of the nicotine is burned up. Cigarettes are often made of weak tobacco. A cigarette does not contain so much tobacco as a cigar. Hence a cigarette does not cost much. It can be smoked in a hurry. It doesn't make a boy so sick as cigars do. Boys and men use a great many cigarettes where they would not touch a cigar. This makes the smoking of cigarettes the most dangerous form of smoking. Selling cigarettes to young boys is forbidden by law.

Habit—When men have used tobacco for some time, they like it and feel bad without it. So they get into the habit of using it, and find it hard to stop. The tobacco seems to help them, but it doesn't do so. It cheats men, and they do not know it.

Chewing gum—Chewing gum is made from pitch or paraffin, for those substances will not dissolve in the mouth. The gum is flavored with sugar and spices. The gum and its flavors are not harmful in themselves, and yet chewing them is harmful. Chewing makes a great deal of saliva flow. All this saliva is wasted, and when we eat our meals we may have too little. Then our food will not digest well, but we shall have dyspepsia and headaches.

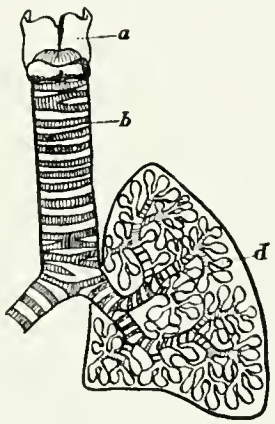
By pulling and handling the gum while chewing it, you may get some poisonous dirt into your mouth, and make yourself very sick.

Even if your gum should not harm you, there is a very good reason for letting it alone. When you chew gum, you look as if you were chewing tobacco. No one likes to see a boy or girl even appear to be chewing tobacco. If you form a habit of chewing gum you will be more likely to chew tobacco when you are grown.

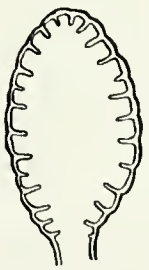
Extracts from Chapter X—BREATHING

The lungs—Our food becomes blood and feeds the cells of our body, but we grow only a little heavier. What becomes of the food?

Besides food, air is always getting into our bodies. In breathing, air passes through the nose into a tube in the neck. This tube is called the *windpipe* You can feel it as a pile of hard rings in the front part of the neck. The windpipe divides into many branches. At the end of its smallest branches are little bags or sacs. The branches and the sacs make the two lungs. So a lung is a soft and spongy piece of flesh, and can be blown up like a rubber bag. A frog's lung is a single, thin bag, about half an inch across. Each little sac of a man's lung is like a tiny frog's lung.



The air tubes and lung.
a larynx or voice box.
b trachea or windpipe.
d air sacs, each like a tiny frog's lung.



A frog's lung

The diaphragm—The lungs fill the upper part of the body just below the neck. They are covered by the bony ribs, and rest upon a broad muscle. This muscle is called the *diaphragm.* It divides the inside of the body into two parts. The upper part is the *chest*, and holds the heart and lungs. The lower part is the *abdomen*, and holds the stomach, intestine, and liver, and a few other parts.

The parts inside the body.
a lungs. *d* stomach
b heart *e* liver
c diaphragm *f* intestine

Breathing—When the diaphragm lowers itself, or the ribs are raised, the chest is made larger. Then the air rushes through the nose and swells out the lungs to the size of the chest. This is taking a breath. Then the chest becomes smaller again, and blows the air out. A man breathes about eighteen times a minute. He does not seem to rest in breathing, but as he works only when he takes in breath, he rests one half of the time.

How air gets into the blood—After the blood has been around the body through the arteries and capillaries and veins, the heart sends every drop to the lungs before it sends it out to feed the cells again. The blood flows through little capillaries upon the sides of the air sacs. There the red blood cells take up some of the air, and carry it with them. When they have a load of air, they become of a brighter red color. The blood in the arteries on its way to the cells is bright red.

How the cells get air—When the blood reaches the capillaries around the cells of the body, the red blood cells give up some of the air to the cells. Thus each cell of the body gets some air, and so it breathes. The cells cannot reach the air themselves, and so the red blood cells bring it to them. We breathe so as to supply the cells with air.

What burning is—When meat is put into a hot stove it quickly burns, and passes off in smoke, and leaves only a little ashes. The ashes are the mineral parts of the meat. If the fire is very hot, you cannot see the smoke. The burning of the meat makes heat. Heat in a steam engine makes the machine do work.

Every fire must have plenty of air. If air is shut off, the fire goes out. When meat burns, the air unites with the meat and makes smoke, and ashes, and gives out heat. Air unites with something in every fire.

Burning inside the body—In every part of a man's body a very slow fire is always burning. The blood brings to the cells food from the intestine, and air from the lungs. The food and air join in a burning. The smoke goes back to the blood and is carried to the lungs, and breathed out with the breath. The ashes, also, go back to the blood, and are carried away by the skin and kidneys. The burning makes no flame or light for it goes on very slowly. You cannot see the smoke, but you can feel the warmth of the burning. Some of the heat is turned to power, and gives the body strength to do work. The body is like a steam engine. It burns up all its food.

Change of air—After air has been breathed it is no longer fit for use. In an hour or two you would breathe all the air of a small room once if it were not changed. When the air is partly used, you feel dull and short of breath and your head aches. As soon as you get out of doors, you feel better. Foul air of houses and meeting places often contains disease germs. It is necessary to change the air of all rooms often. You can do this by opening a door or window. It is a good plan to sleep with your bedroom window open, so as to get good air all night.

Air passes in and out of every crack in the windows and doors. If only one person is in a room, this may make enough change of air. If many persons are in a room, you will need to change the air in other ways. You can do this by opening a door or window. Do not let the cold air blow upon any one, for it may help him catch cold, if the air of the room is impure. If we lower a window from the top, warm impure air may pass out above it without making a draft.

You need fresh air at night as much as in the daytime. You need not be afraid of the night air, for it is good and pure like the day air. You ought to sleep with your windows open a little. You ought to open your windows wide every morning and air your bed well. At night you ought to take off all your clothes and put on a night-dress. Then hang your clothes up to air and dry.

When to air a room—When you first enter a room full of bad air it smells musty and unpleasant. But after you have been in the room a while you get used to it. If, however, you go out of doors a minute and then come back, you will smell the bad air again. If the air smells bad, open a door or window until it is sweet again.

How to breathe—When you run hard, the cells of your body use up all the air, and then you feel short of breath. While you run, burning goes on faster, and you feel warmer. You can

work harder and longer if you can breathe in a great deal of air. You will also feel better and stronger for it. Then if you are sick, you will be able to get well more quickly. You ought to know how to breathe right.

First, you ought to breathe through your nose. Even when you run, you ought to keep your mouth closed.

Second, you should try to breathe deeply. You should take a very deep breath often, and hold it as long as you can. By practice you can learn to hold it a full minute.

Third, you ought to run, or do some hard work, every day. When you get short of breath, you will have to breathe more deeply. After a while you may be able to run a half mile, or even a mile, without getting out of breath. But do not get tired out in your run, for this will harm you.

Fourth, you must sit and stand with your shoulders back, and your chest thrown forward. A round-shouldered boy cannot have large lungs or be long-winded.

By breathing right, you can make your lungs much larger and stronger.

Alcohol and the lungs—If you run a long race, your lungs will need a great deal of air. If you take strong drink, the alcohol will use up much of the air, and you will not have enough to use on your run. So you will feel short of breath and will surely lose the race. You cannot drink and be long-winded.

Two drinks of whiskey will use up as much air as the body uses in an hour. It would be easy to smother a person with strong drink. Drunken persons are really smothered; they often die because of the failure of their breathing, even while their heart is able to beat well.

Alcohol often causes the lungs to become thickened. Then air cannot easily pass through their sides, and a person suffers from shortness of breath. Sometimes these persons cannot lie down at all, but must sit up to catch their breath.

How tobacco affects breathing—We would not live in a room with a smoking stove. But tobacco smoke is more harmful than smoke from a stove, for it has nicotine in it. Tobacco smoke in a room may make a child sick.

Cigarette smoking is very harmful to the lungs, for the smoke is drawn deeply into them, and more of the poison is likely to stay in the body. The smoke of tobacco burns the throat and causes a cough.

CORRECTION

An error occurred in Equation 1 of Chatburn's "Classification of Mechanical Ventilators" (Respir Care 1992;37:1011). The corrected equation is shown below, we encourage you to cut it out and paste or tape it over the incorrect copy. We regret the error.

$$\text{muscle pressure} + \text{ventilator pressure} = \text{volume/compliance} + (\text{resistance})(\text{flow}). \quad [1]$$

Answers to Calculations in "Murder Mystery" for Student Practice of Pulmonary Physiology Calculations

Michael B Maron PhD and Frank J Bosso PhD

The October 1992 issue of this journal contained the above-mentioned Murder Mystery. Readers were challenged to discover the murderer's identity by calculating various pulmonary physiologic values in order to fill in the missing numbers in five tables. Here, we publish those tables with the answers in boldface type. Knowing these values enabled sleuth Madeline Medstudent to unmask the murderer. Readers are invited to do the same.

Table 1. Calculations To Determine CO Poisoning

Arteriovenous oxygen content difference	**5.0** mL O_2/dL
Arterial oxygen content in presence of 80% carboxyhemoglobin	**4.2** mL O_2/dL

Drs Maron and Bosso teach in the Department of Physiology, Northeastern Ohio Universities College of Medicine, Rootstown, Ohio. This "Murder Mystery" is published with permission of the authors, in slightly modified form, based on a version that originally appeared in Am J Physiol 261 (Adv Physiol Educ 6):S3-S6, 1991.

Table 2. Arterial O_2 Content and Maximal O_2 Delivery Rate Values

Suspects	[Hb] (g/dL)	P_{aO_2} (torr)	Sat (%)	$\dot{Q}$ (L/min)	C_{aO_2} (mL/dL)	Max Del (mL/min)
Davenport	15	97	98	20	**20.72**	**4,144**
Daphne	12	95	97	16	**16.46**	**2,634**
Victor	8	98	98	30	**11.19**	**3,357**
Aldo	8	70	90	12	**10.22**	**1,226**

These data eliminate **Aldo** as a suspect.

Table 3. Maximal and 75% Maximal O_2 Delivery Rate Values

Suspects	Maximal Delivery (mL O_2/min)	75% Maximal (mL O_2/min)
Davenport	**4,144**	**3,108**
Daphne	**2,634**	**1,976**
Victor	**3,357**	**2,518**
Aldo	**1,226**	**920**

These data eliminate **Daphne** as a suspect.

Table 4. Ventilatory Calculations

	Davenport	Daphne	Victor	Aldo
Control conditions				
Mixed expiratory P_{CO_2} (torr)	27	29	23.6	22
Arterial (= alveolar) P_{CO_2} (torr)	40	39	40	38
Tidal volume (mL)	510	450	487	400
Physiologic dead space (mL)	**166**	**115**	**200**	**168**
Total ventilation (mL/min)	5,100	5,400	5,844	6,000
Respiratory rate (breaths/min)	10	12	12	15
Dead-space ventilation (mL/min)	**1,660**	**1,380**	**2,400**	**2,520**
Alveolar ventilation (mL/min)	**3,440**	**4,020**	**3,444**	**3,480**
Added dead space (note respiratory rate remains constant)				
Snorkel + physiologic dead space (mL)	**301**	**250**	**335**	**303**
Dead-space ventilation (mL/min)	**3,010**	**3,000**	**4,020**	**4,545**
Total ventilation (mL/min)	**6,450**	**7,020**	**7,464**	**8,025**

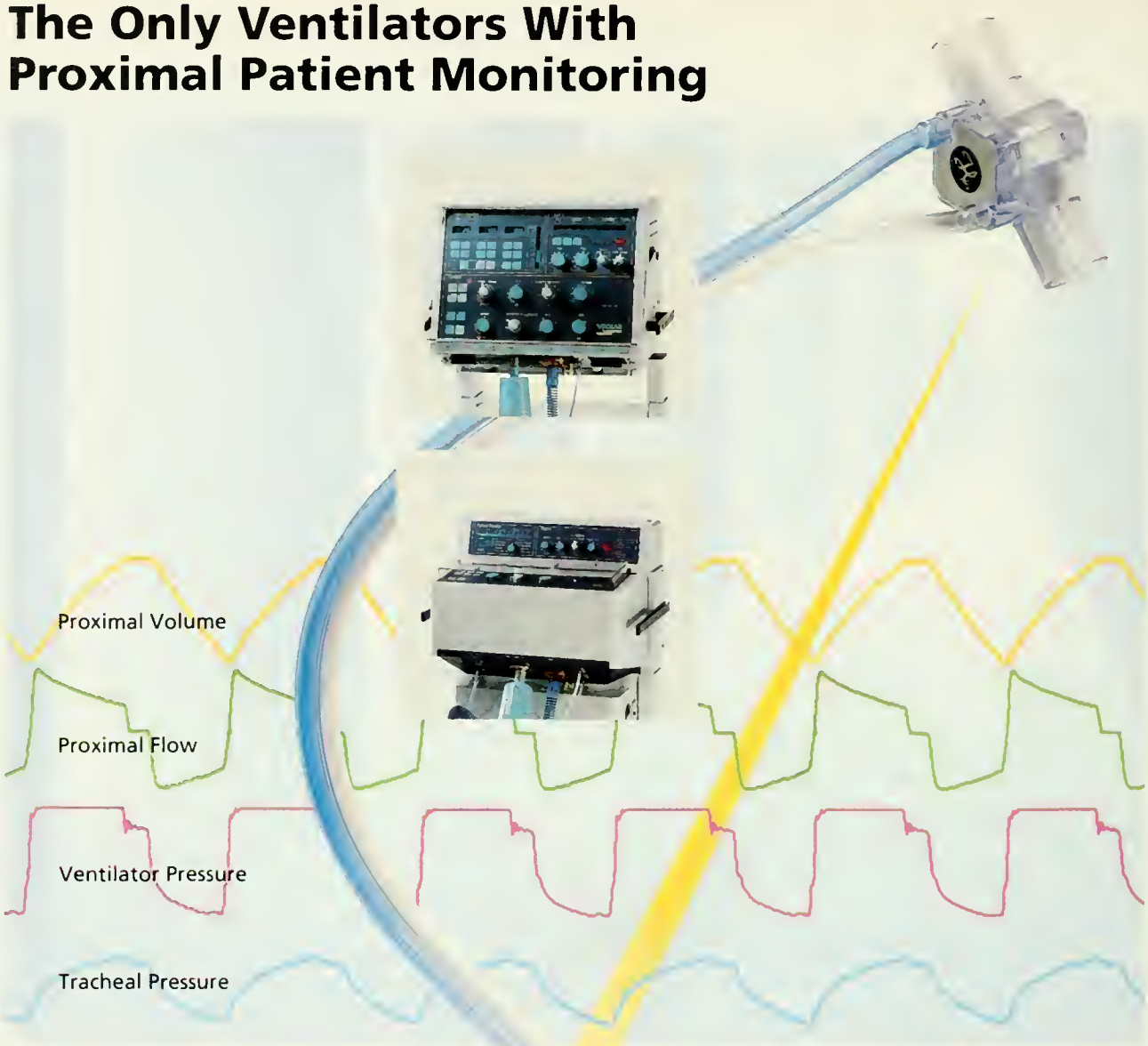
The identity of the murderer is now clear.

Table 5. Determinations of Alveolar P_{O_2} and P_{CO_2} Values

	Davenport	Daphne	Victor	Aldo
Total ventilation under control conditions (mL/min)	5,100	5,400	5,844	6,000
Dead-space ventilation with added dead space (mL/min)	**3,010**	**3,000**	**4,020**	**4,545**
Alveolar ventilation (mL/min)	**2,090**	**2,400**	**1,824**	**1,455**
Alveolar P_{CO_2} (torr)	**65.8**	**65.3**	**75.5**	**90.9**
Alveolar P_{O_2} (torr)	**62.8**	**63.4**	**50.7**	**31.4**

Whodunit? The murderer's name will be revealed in the December issue's Table of Contents.

The Only Ventilators With Proximal Patient Monitoring



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The 1992 RESPIRATORY CARE OPEN FORUM

Each year a highlight of the Annual Meeting of the American Association for Respiratory Care, the RESPIRATORY CARE OPEN FORUM, provides a platform for the reporting and discussion of some of the clinical studies, methods and device evaluations, and case reports completed by members and friends during the previous year. During the 1992 OPEN FORUM in San Antonio, Texas, December 12-15, more than 120 papers will be presented—clustered into 12 minisymposia. The abstracts of those papers are published here, sequenced as they will be presented. An index of the authors appears on page 1372, with Presenters designated by boldface type.

Cost Reductions, Quality Improvement, and Protocols

Reduction of Unnecessary Care through Utilization of a Respiratory Care Plan—Rich Malloy RRT, Margie Pierce CPFT RRT, Don Friel MEd RRT, Philip McElroy MD. Fox Chase Cancer Center, *Philadelphia, Pennsylvania.*

Efforts to contain costs in our respiratory care department caused us to look at respiratory procedures ordered by physicians. We found that a significant amount of ordered therapy was unnecessary or was not discontinued in a timely manner. This increased costs to patients and required 16-full time employees (FTEs) to perform the ordered work. We formed a team of respiratory therapists, managers, and the medical director to find a solution to this problem. The team's goal was to focus available resources on patient problem resolution while providing the most efficient, least invasive intervention. They developed the Respiratory Care Plan. The Plan classified patient respiratory diagnosis/symptoms into 5 categories: decreased oxygen level, bronchospasm, prevention of atelectasis, treatment of atelectasis, and ineffective airway clearance. The physician implements respiratory care by indicating the respiratory diagnosis. The therapist then performs a complete assessment and develops a care plan for the patient. Branching logic scenarios were developed for each diagnosis to guide the therapists in their decision making. Therapy is evaluated shift by shift and modified or discontinued if needed. The Respiratory Care Plan was then endorsed by the Quality Assurance Committee and was approved by the Medical Executive Committee. After extensive in-service training of physicians, nurses, and respiratory therapists, the Care Plan was implemented. At 24 months after implementation, we observed the following reductions: bronchodilators by 49%, chest physiotherapy by 93%, and incentive spirometry by 17%. We then reviewed 2 diagnosis-related groups to evaluate patient impact. Length of stay for thoracotomy patients was 11.84 days pre-Care Plan and 10.36 days post-Care Plan. Length of stay for pneumonia patients was 7.53 days and 6.86 days, respectively. We also reviewed chest x-rays of thoracic surgery patients and found no increase in atelectasis postoperatively. The outcome after 24 months of using a Respiratory Care Plan has been a marked reduction in unnecessary procedures resulting in savings to the patient and hospital, improved documentation of Medical Necessity by physicians, improved staff morale, and no negative outcome to the patient. (OF-92-044)

Analysis of an Endotracheal Intubation Service Provided by Respiratory Care Practitioners—Janice J Thalman BS RRT, Susan Rinaldo MEd RRT. Duke University Medical Center, *Durham, North Carolina.*

Introduction: Our Respiratory Care Services provides an endotracheal intubation service and responds to all intubation calls. Intubation is performed by registered respiratory therapists who have completed an 8-hour training program, ACLS certification, and clinical performance of intubation with supervision. 4 RCPs/shift carry emergency equipment. Goals of this service are (1) to provide competent individuals for performing this service, (2) to assure a rapid response time, and (3) to be cost-effective. A retrospective analysis of our service was conducted over a 1-year period and calculations were made of the intubation success rate, complication rate, and response time. Cost-effectiveness was assessed by calculating money saved thru centralizing the service. **Results:**

Outcomes of 833 Requests for Intubation 7/1/90 - 6/30/91

Successful Intubations	Successful in < 3 Attempts	Recognized Complications	Major Complications	Average Response Time
791 (94.9%); 222 (28%) were cardiopulmonary arrest	730 (92.3)	96	0	54 seconds

Recognized complications included oral bleeding, vomiting, and short periods of oxygen desaturation. In the 5.1% (42) of the patients not intubated by our service, 22 required heavy sedation and an anesthesiologist was consulted. 17 patients were intubated by other physicians and 3 tracheostomies were indicated. Multiple attempts were a result of secretions, bradycardia, blade-light malfunction, damaged cuff, esophageal tube, and prior attempts by other personnel. The longest documented time between first attempt and successful intubation was a 20-min interval awaiting Anesthesia response. Cost savings were realized by centralizing equipment. 8 complete emergency boxes are maintained. Inventory control and equipment function are checked every shift. The cost of each box is $3,000 ($24,000 total). Without centralization, this would need to be duplicated on 150 code carts in the hospital at a cost of $450,000. The salary difference between an anesthesiologist and a respiratory care practitioner is an additional savings. **Conclusions:** Respiratory Care Services can provide an effective intubation service. Providing this service has resulted in an increased clinical visibility and credibility, enhanced physician/practitioner rapport, a recruitment tool, a performance incentive, and improved intradepartmental hospital interaction. (OF-92-089)

Cost Savings associated with Training Patients To Self-Administer Metered Dose Inhalers—Linda M Folk RRT, Carl F Haas MLS RRT, John G Weg MD, Teresa Keppler RRT, Mark A Konkle BHA RRT. University of Michigan Medical Center, *Ann Arbor, Michigan.*

Introduction: Methods to reduce costs in respiratory care departments are receiving increasing attention. In our institution, administering bronchodilators by small volume nebulizer (SVN) had required a respiratory care practitioner (RCP) at the bedside for 15 minutes. In January 1989, we initiated the use of supervised metered dose inhalers (MDIs) with spacer chamber, as the primary mode of medication delivery. In September 1989, we established that some patients using a MDI could administer the bronchodilators unsupervised (SA) after proper instruction by trained personnel. Our study objective was to evaluate success of SA protocol with emphasis on quality care with cost savings. **Methods:** Patients were considered for SA protocol if they had (1) bronchodilator indication with stable respiratory status, (2) physical capability of using MDI, (3) mental capability of understanding the procedure, and (4) motivation to learn procedure and follow protocol. Once criteria were met, patients were instructed by an RCP on the rationale for therapy, information about their specific medication (eg, name, dose, indications, side effects) and procedure. Patients then demonstrated proficiency for 24-72 hours under supervision by an RCP. Patients were instructed to chart date and time that they administered treatments and any side effects encountered, on a bedside form that became part of the medical record. Patients were reassessed by an RCP every 3 days until therapy was discontinued or they were discharged. Data from January 1991-March 1992 were retrieved from a departmental database and from a random sample of 41 medical records. **Results:** The average (SD) SA patient was 54.5 (18) years old, was male (51%), had COPD (83%) as an indication for therapy, was hospitalized for 11.8 (8.2) days, was on bronchodilators for 10.5 (7.4) days, had received SA training for 1.4 (1.0) days, was on SA protocol for 6.2 (5.7) days, and was discharged with bronchodilators (85%). Of all general care (GC) bronchodilator treatments, 74,983 (81%) were MDI and 13,722 (18.3%) of these were SA. No patient reverted to supervised MDI from SA in the 41 charts reviewed. In addition to extensive supervision received by the MDI patients vs SVN, SA patients had objectively documented compliance in self-administration of MDI. Cost analysis showed (1) a labor savings of $3.71/SA treatment, resulting in a $50,841 annual department savings; and (2) potential annual reduction in charges of $672,378. **Conclusions:** Self-administration of bronchodilator medication via MDI in hospitalized patients is safe and effective; it appears to improve patient use of the MDI. An SA program can reduce costs to respiratory care departments and provide considerable annual savings in charges. We found the program well accepted by the medical staff, RCPs, and patients. (OF-92-094)

Variable Effect of Earned Time on Absenteeism in Respiratory Care and Physical Therapy Departments—LeeAnn Dobro RRT, David Romagnoli MS RRT, Robert M Kacmarek PhD RRT. Massachusetts General Hospital, *Boston, Massachusetts.*

Absenteeism is a major problem in most hospitals and is associated with reduced productivity and poor employee morale. Over the last 3 years, the Respiratory Care Department at Massachusetts General Hospital has had in effect a "no fault" disciplinary program directed at reducing absenteeism. On March 31, 1991, a hospital-wide Earned Time Program (paid personal leave, consolidated annual leave) went into effect. We compared the effect of instituting Earned Time (ET) on the Respiratory Care and Physical Therapy Departments. The Physical Therapy Department has no absenteeism-reduction disciplinary program. **Methods:** Prospective absenteeism data on 40 Respiratory Care Practitioners (RCP) were collected during the 6-month periods: June-November 1990 and June-November 1991. These periods were chosen to allow for an Earned Time 'burn-in' period and to eliminate the effect of seasonal variations on absenteeism. Retrospective data on 35 physical therapists (PT) were also collected during the same periods. Data for both groups were only collected on individuals continuously employed during the period June 1990-November 1991. **Results:** RCP absenteeism pre-ET (mean, SD) 18.5 (16.5) hours vs post-ET 27.4 (35.8) hours absenteeism, $p = 0.147$. PT pre-ET 24.3 (50.5) hours vs post-ET 5.14 (9.5) hours, $p = 0.033$. **Conclusion:** Earned Time had a significant effect on PT absenteeism but not RCP. Potential reasons for this discrepancy are the presence of a disciplinary program, the requirement for shift rotation, and the need for 24-hour/day coverage within the Respiratory Care Department. (OF-92-101)

Outcome of a Pediatric Utilization Review Program for Intermittent Respiratory Therapy—Thomas Malinowski BS RCP RRT, Gerald Ellis MBA RCP RRT, Ronald Perkin MD, Philip M Gold MD. Loma Linda University Medical Center, *Loma Linda, California.*

Introduction: Intermittent respiratory therapies such as aerosol therapy (small volume nebulizer, SVN, and metered dose inhaler, MDI) and chest physiotherapy (CPT) account for a significant portion of respiratory care labor use in pediatrics. During period 1988-1991, total volume of intermittent therapies at our hospital increased by 27% despite an effective Utilization Review program (UR) in adult patient care areas. As a result, the department researched and developed utilization guidelines for pediatric patients with cardiopulmonary disease. A quality improvement study identified that many treatments did not meet utilization criteria. The medical staff approved the guidelines, and the pediatric UR program was implemented. We report results of this pediatric UR program. **Methods:** This retrospective study compared average monthly procedure volumes, direct labor hours, patient days, admission rates, length of stay (LOS), and respiratory-related diagnoses for pediatric patients treated at our hospital from January 1991-August 1991 (Pre-UR) to September 1991-March 1992 (Post-UR). Procedure volume was obtained from documented activities retrieved from the departmental information system. Patient days, admission rates, length of stay, and respiratory-related diagnosis data were obtained from the hospital information system. t and F test statistics were used for analyses. **Results:** No statistically significant difference (ns) was found between the 2 periods for patient days, admission rates, aerosol, LOS, or respiratory-related diagnoses ($p < 0.05$). There was a statistically significant change in monthly labor hours, total procedures, SVN, CPT, and MDI after implementation of the pediatric UR program ($p < 0.05$).

	Mean/Month			
	Pre-UR	Post-UR	% Change	p Value
Total procedures	5180	3117	–40%	< 0.05
Aerosol	3311	2513	–24%	ns
SVN	3102	1763	–43%	< 0.05
MDI	209	750	+259%	< 0.05
CPT	1869	604	–68%	< 0.05
Direct labor hrs	1465	802	–45%	< 0.05
Patient days/unit	580.8	560.8	–3%	ns
Admissions/unit	69.9	76.5	+9%	ns
LOS	5.5	5.6	+2%	ns
Respiratory diagnoses	116	139	+20%	ns

*by Student's *t* test.

Conclusions: Both CPT and SVN aerosol procedures were significantly reduced after implementation of UR program. MDI procedures increased as a result of guidelines recommending MDI as a substitute for SVN. Total aerosol procedures were reduced by 24% (ns). Direct labor hours were reduced by a greater percentage than total procedures, reflecting a more efficient use of labor. A reduction in total procedures despite an increase in respiratory diagnoses implies more appropriate use of intermittent therapy. In conclusion, a pediatric UR program can assist bedside respiratory care practitioner and physician in optimizing patient care, reducing procedure volume, and improving productivity. (OF-92-112)

An Evaluation of Physician-Directed Respiratory Care in a Pediatric Teaching Institution—Nancy Lowe RRT. Arkansas Children's Hospital, *Little Rock, Arkansas.*

Background: The current method used to manage respiratory care administered to patients at our institution is the traditional physician-directed system. A recurrent problem with this system is overuse of available services. **Method:** I performed a retrospective study of patient charts to evaluate appropriateness of therapy ordered by physicians. Criteria, identified from department policies and quality improvement guidelines, included documented indications for therapy, positive patient response to therapy, radiologist interpretation of chest x-rays, and changes in the frequency of therapy as patient condition improved. **Results:** 116 charts of patients hospitalized between December 1989 and October 1992 were randomly selected and reviewed. Of those patients, 30 (26%) received unnecessary therapy: 18 no documented indications, 5 therapy continued after CXR cleared, 3 therapy q4h or more often at discharge, 3 contraindicated therapy ordered, and 1 therapy continued despite no response. **Discussion:** During this era of cost containment and prospective reimbursement, respiratory care practitioners realize the importance of avoiding unnecessary expenses; however, it is equally imperative to provide excellent patient care. Unnecessary therapy takes personnel time from patients who do require our services. **Conclusion:** This study concludes that in our institution our current physician-directed system of ordering respiratory care is inefficient, failing to meet our QI standard of 90% appropriateness. To make the most effective use of our resources, we must develop a system for respiratory care that eliminates unnecessary therapy. (OF-92-124)

Reduction of Length of Time on Mechanical Ventilation by Use of a Multidisciplinary Weaning Protocol—William R Anton RRT, Pam Wilhelm RN MN CCRN, Terry Jordan BS RRT. University of Washington Medical Center, *Seattle, Washington.*

After developing a mechanical ventilation (MV) weaning protocol, we conducted a study to determine its impact on length of time on MV and number of ABGs drawn. **Method:** The population was post-cardiothoracic surgery patients who were extubated in < 24 hours. After the patient had arrived in the ICU and stability had been determined, "wean by protocol" was ordered by the physician. The respiratory care practitioner (RCP) and registered nurse (RN) then collaborated to wean (decrease) the ventilator F_{IO_2}, IMV rate, and PEEP, and to perform a T-piece trial, extubate, and decrease F_{IO_2}. Data were collected for consecutive 2-week periods 3 months prior to and

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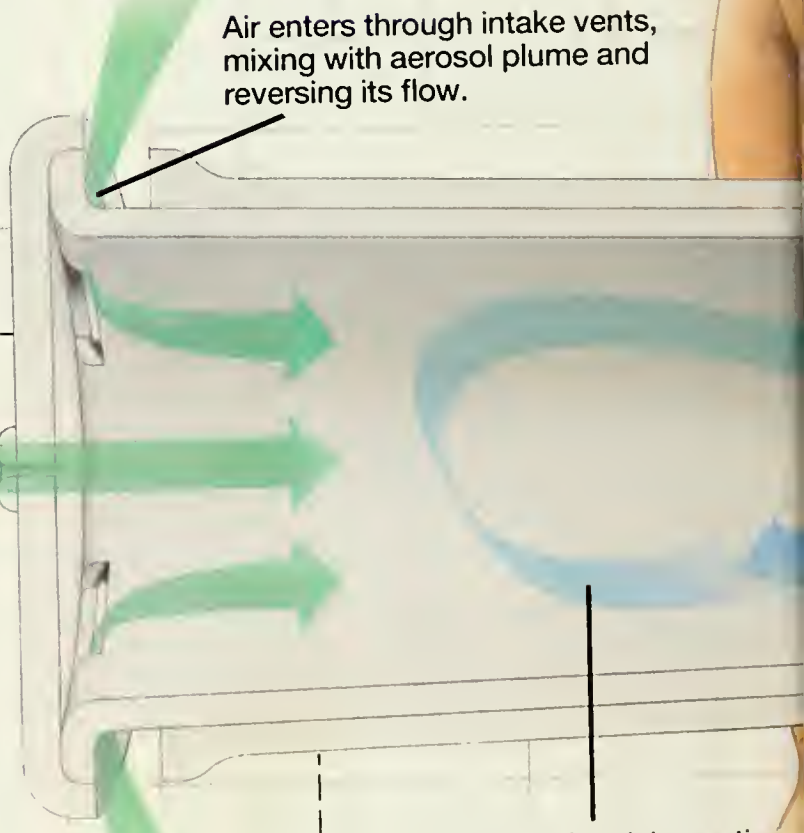
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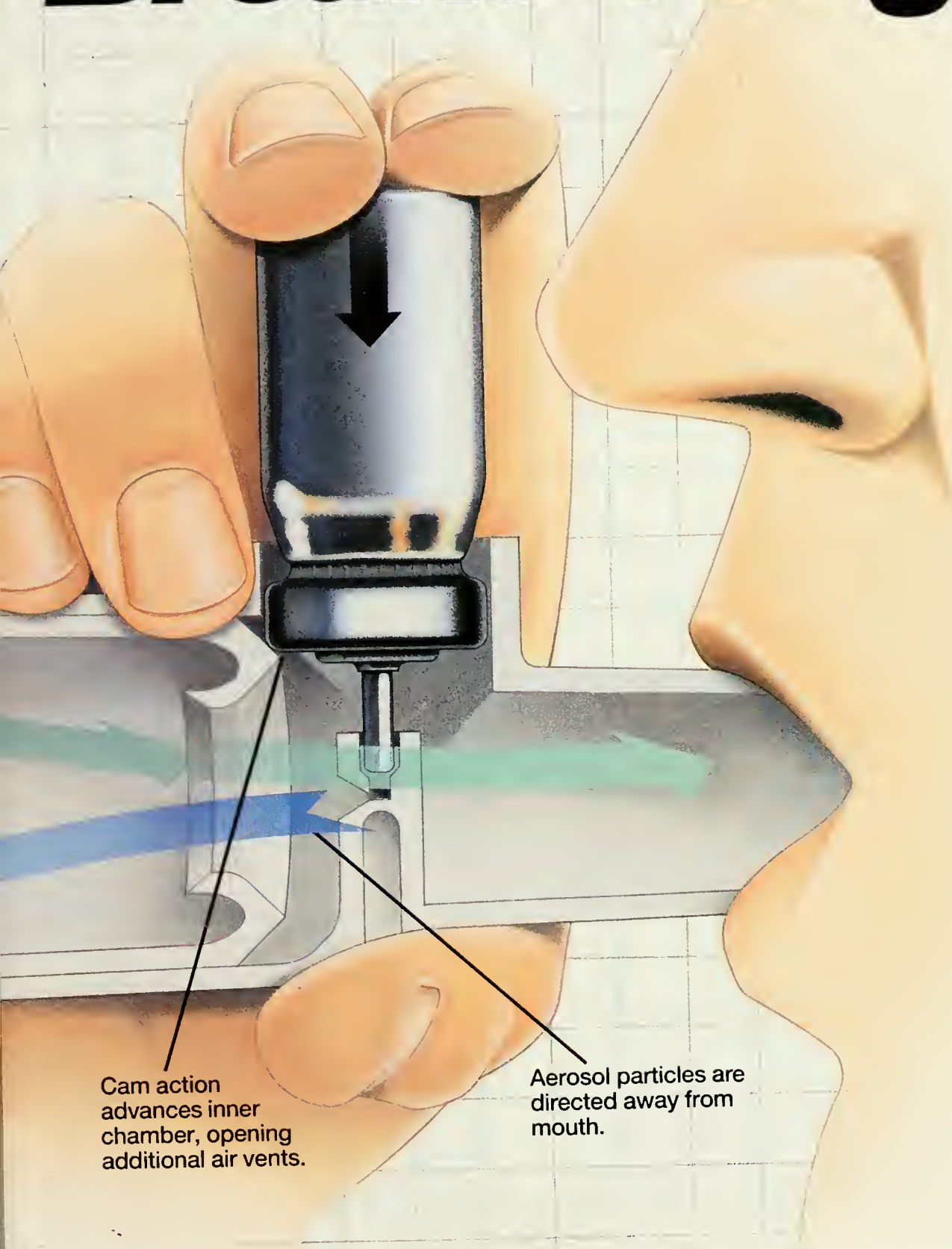

References: 1-2. Data on file, HealthScan Products Inc. U.S. Patent No. 5,040,527 OA760002-0 8/92

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both 7 and 10 months post-protocol. **Results:** Pre-protocol mean time on MV was 18:10 h:min (range 8:10-23:20) (n = 37), decreasing to 14:45 h:min (range 5:00-22:27) (n = 38) and 13:00 h:min (range 2:50-21:08) (n = 35) at 7 and 10 months, respectively. The mean number of ABGs pre-protocol was 7.6 (1 every 2.4 h), post-protocol 7.5 (1 every 1.9 h) and 6.8 (1 every 1.9 h). No patients required reintubation. **Conclusion:** Postsurgical length of time on MV was reduced by use of a weaning protocol managed by RCPs and RNs. Total number of ABGs decreased, but not ABGs/h. Potential cost savings include more efficient use of personnel and equipment, decreased medication secondary to increased patient comfort, decreased time in ICU, and decreased MV risks. Subjective employee satisfaction was positively affected by increased involvement in the decision-making process and enhancement of teamwork among ICU staff. (OF-92-129)

Early Experience with the Respiratory Therapy Consult Service at the Cleveland Clinic Foundation—David Haney RRT, Lucy Kester MBA RRT, Dennis Giles RRT, John J Komara Jr BA RRT, Lawrence C Fergus MBA RN RRT, James K Stoller MD. The Cleveland Clinic Foundation, *Cleveland, Ohio.*

To assess early impact of our Respiratory Therapy Consult Service (RTCS) on clinical practice patterns, we compared type and intensity of respiratory care (RC) services delivered to 20 RTCS patients (pts) undergoing upper-abdominal surgery vs 20 pts whose RC plan was determined by MD's orders (non-Consult patients). After inception of RTCS on 1/27/92 and orientation of colorectal surgeons and nurses, these MDs could select either RTCS to manage their pts' RC (ie, based on Therapist Evaluators' plans using symptom/sign-based algorithms) or traditional, MD-driven plans. Of 82 pts receiving respiratory care after upper-abdominal surgery between 2/1 and 3/31/92 (31 Consults, 51 non-Consults), 20 Consults and 20 non-Consults were randomly selected for comparison. To further examine changes in ordering practices over time after inception of RTCS, randomization was blocked to identify 10 Consult and non-Consult pts undergoing surgery in each of 2 months after RTCS onset. Patient groups were compared with respect to severity of respiratory illness based on a "Triage Score" (1 to 5, where 1 = highest acuteness) developed to assess acuteness at CCF, type and frequency of RC services, and outcomes, including hospital length of stay and cost of care (total and respiratory care services). Analysis of a convenience sample of 10 patients whose Triage Scores were available from retrospective chart review showed a trend towards more severe respiratory illness among Consults [mean (SD) Triage Score 3.0 (0.73) vs 3.9 (0.32), p = NS]. Consistent with greater severity of respiratory illness, RTCS pts received more types of RC services per pt [mean (SD) 3.4/pt (1.6) vs 2.35/pt (1.5), p = 0.034] and more total RC treatments per pt [38.1 (27.2) vs 11.7 (11.9), p = 0.0005]. Also, RTCS pts were more likely to experience adjustment of respiratory care plans after first 24 h of therapy than non-Consult pts [1.5 (1.50) additional orders/pt vs 0.45 (0.89), p = 0.011], suggesting that RTCS provided more active adjustment of therapy than non-Consult care. Also consistent with higher acuteness in RTCS patients, a trend towards longer hospital length of stay was seen in RTCS pts [13.0 (11.7) vs 9.8 (5.9), p = 0.24] and total respiratory charges were greater [$1,629/pt ($1,592) vs $390/pt ($427), p = 0.003]. Finally, comparison of Consult pts treated in February vs March 1992 showed no significant differences. This preliminary study suggests that (1) an RTCS can be implemented in a large tertiary teaching hospital with widespread MD and nursing acceptance; (2) among pts undergoing upper-abdominal surgery, those selected by surgeons for RTCS showed a trend toward more severe respiratory illness based on a Triage Score; (3) although greater length of stay and charges are in keeping with RTCS pts' having more severe respiratory illness, the possibility that RTCS contributes to more care cannot be excluded by this preliminary study; and (4) although no difference in practice was seen between Months 1 and 2 after RTCS began, continued study may demonstrate changing practice patterns. (OF-92-134)

The Relationship between Absenteeism and Non-Participative vs Participative Schedules—Gary Gradwell BS RRT, Dorisanne D Miller RRT, Stephen J Connell BA RRT, Herbert Patrick MD, Paula Levine MBA RN. Thomas Jefferson University Hospital, *Philadelphia, Pennsylvania.*

We compared the rate of nonscheduled absenteeism when two different scheduling techniques were used in the Respiratory Care Department. Data were analyzed from 6 months of a supervisor-generated, non-participative schedule that varied days off, consisted of 8-hour shifts only, included limited shift rotation, offered 2 out of 3 weekends off, and was reconstructed every 2 weeks. Those data were compared to a 6-month period following implementation of a 6-week repeating schedule that involved the staff in the selection of their permanent schedule, offered 2 out of 3 weekends off, and offered either a schedule of five 8-hour shifts/week, or two 8-hour and two 12-hour shifts/week, or four 10-hour shifts/week with no shift rotation. This participative schedule was a new method instituted in our department due to inconsistencies in scheduling patterns over the days and shifts of the week and rising pool and agency usage. 39 practitioners were included in this method evaluation. The quantitative analysis for nonscheduled absenteeism revealed a decrease from 143 days to 109 days at the end of the first 6 months of the new participative schedule. Of the 39 practitioners studied, 21 decreased absenteeism by 76 days, 2 stayed the same, 12 increased absenteeism by 24 days, and 4 increased absenteeism by 18 days during the 6-month period. It must be noted that these four practitioners declined to participate in choosing their schedules. The net decrease was 34 days. We conclude that there is a strong relationship between the participative schedule design and decreased nonscheduled absenteeism. Even though absenteeism was not a major reason for developing the participative schedule, this favorable change in attendance is viewed as an added benefit. Further investigation is required to determine the related influential factors such as seasonal fluctuations, work load, and other contributing factors. (OF-92-143)

Primary Patient Care Task Force: A Strategy To Change Utilization Patterns, Improve Quality, and Reduce Costs Outside of the Critical Care Unit—James B Fink MS RCP RRT, Jack Covington BA RCP RRT. UCSF Medical Center, *San Francisco, California.*

Introduction: Our 560-bed tertiary medical center has developed clinical initiatives to shift ordering patterns from common time-consuming respiratory care procedures to more effective alternatives requiring less therapist time [eg, bronchodilator dosage to relief in acute asthmatics, shifting from small volume nebulizer (SVN) to MDI with holding chamber, implementing NIH Asthma Management Guidelines, and substituting positive expiratory pressure (PEP) therapy for postural drainage therapy (PDT)]. Strategies have been successful with many patients but negotiating with physicians to adopt alternative approaches and providing consistent training and communication from shift to shift has been difficult. We created a primary patient care (PPC) task force (TF) whose goals were to evaluate impact of having small number of specially trained staff to provide standardized care on acute care floors (emphasizing quality of care, improved operations, and communication); to develop role of RCP as a clinical consultant to perform patient assessment and make recommendations for care; to increase medical staff's confidence in RCP to recommend and implement care plans; and to identify opportunities for improving quality of care and department operations. **Method:** TF consisted of 3 RCP volunteers from each shift to serve for 4 months (with backup by supervisors). Each RCP and supervisor was assessed for ability to present rationales and perform key procedures. A handbook included key department policies, rationales, and supporting materials (eg, AARC Clinical Practice Guidelines, Aerosol Consensus Conference Proceedings). Subsets of documents were distributed to physicians. TF met monthly to identify problems and opportunities and to develop improvement strategies. **Results:** In first week of TF implementation, a 45% reduction in therapy volume occurred on floors (from 14 h of direct patient care/12-h shift to 9 h), which was sustained through the 4-month period. Initial orders for MDI increased by 150%, with 50% of SVN orders converted to MDI after initial treatment. Orders more frequent than q3h were reduced by 70%. PDT therapy was reduced by 65%, with a 45% increase in PEP therapy. Audits of diagnostic procedures demonstrated improvement in quality and documentation. **Experience:** TF expressed tremendous satisfaction from promoting effective therapy, educating patients, changing practice patterns, and being viewed as resource to physicians. They felt most effective when following patients through course of therapy (rather than just initiating therapy), and felt follow-through by RCPs with patients and physicians from shift to shift was key, noting that intensity of interactions offers potential for burnout and recommending periodic rotation to non-PPC assignments. **Conclusion:** PPC TF met all goals. Reduction of direct patient care with improved quality (as perceived by RCP, physicians, and patients) resulted in reductions of 1 RCP around the clock (4.5 FTE), representing savings of > $160,000/year. TF demonstrated that involvement of team of highly skilled RCPs as assessors, consultants, and care providers on acute care floors can improve quality with important cost reduction for both hospital and patient. PPC TF team will be expanded by 2 RCPs/month to eventually include all respiratory care staff providing direct patient care. (OF-92-152)

Does a Respiratory Care Information System Improve Charge Capture?—Wadie Williams RCP RRT, John S Sabo MS RRT, Joy E Hargett BS RRT. St Luke's Episcopal Hospital, *Houston, Texas.*

A retrospective review of patient charges was performed to determine whether the use of a respiratory care information system (RCIS) improved our department's charge capture. A comparison was made to the hospital mainframe computer and the charge by exception (CBE) method that was in use prior to implementation of the RCIS. The RCIS method utilizes a personal computer (PC), hand-held barcode reader (BCR), and a local area network (LAN) that connects all of the department's PCs. The CBE method required the use of mainframe-generated, four-copy worksheets (the last copy of which was used for charging purposes) and a light pen to mark the charge that was being credited. The RCIS method utilizes a BCR docking device that is attached to each PC for the transmittal of patient charting and charge data. In both methods, charges are processed the day after service is rendered. **Method**: A 516-day period in which the CBE was utilized was compared to 365 days of RCIS charge data (post-implementation). Variables identified for analysis were average hospital daily census, percentage of patients treated, average daily charges, average daily patients treated, revenue/charge, and revenue/patient. **Results**: Average daily census increased 1.26%; percentage of pts treated increased 4.29%; avg daily charges increased 19.02%; avg daily pts treated increased 6.24%; revenue/charge decreased 5.5%; and revenue/pt increased 5.87%. **Summary & Conclusions:** The use of a RCIS for charge capture has had a postive impact on our department's ability to accurately capture patient charges. Patient data/charge data can be frequently transmitted to the database for inclusion and assembly of the patient's charges. In addition, the ability to configure the charge system in the RCIS to include charges that may be associated with a particular therapy or treatment also reduces the number of lost charges. We recommed the use of a RCIS to enhance department financial performance. (OF-92-174)

Savings Associated with Therapist-Driven Protocols for Bronchodilators—Gary Wickman BA RRT, Dan Lee RRT, Dan Nelson BA RRT. General Hospital Medical Center, *Everett, Washington.*

Because of the rising costs of health care and the tightening of departmental budgets, we looked at the financial impact, both in cost per treatment and in staffing, of implementing therapist-driven protocols for bronchodilator delivery. With our Bronchodilator Protocol, any bronchodilator ordered for an intubated, mechanically ventilated patient is delivered via MDI.

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For spontaneously breathing patients, the RCP determines the most appropriate means of delivery. **Method:** To quantify the financial impact, we looked at 5 months of statistics before and after starting the protocol. We determined the cost of therapy per treatment by adding the cost of medication, equipment, and practitioner time. Practitioner time was based on the Respiratory Care Society of Washington's Uniform Reporting Manual. The cost was $5.77 for initial and $2.15 for routine MDI therapy, and $6.55 for initial and $6.34 for routine SVN therapy. For mechanically ventilated patients, the cost was $1.82 for MDI and $6.34 for SVN. We then determined the average cost per treatment for each month by using the total number of bronchodilator treatments and the total cost based on the above figures. **Results:** For the 5 months before starting our protocol, the average cost of therapy per treatment was $5.83. For the 5 months after starting our protocol, the average cost was $4.09. This is a savings of $1.74 per treatment after implementation of our protocol. To project the savings for a year, we used the savings per treatment ($1.74) and the average number of treatments per month (1,871). This gave a potential savings of $40,000 for the year **Conclusion**: We spent 425 hours per month before and 341 hours per month after, and delivered 1,718 treatments per month before and 2,025 treatments per month after implementation of our protocol. We delivered more therapy in less time after implementation of our protocol and reduced our staffing by 0.5 FTEs. This is a significant savings by simply using MDIs when appropriate. Currently, we are delivering about 50% of our bronchodilator treatments via MDI. We communicated these results to our physicians, but we need to look at how the use of the protocol affects patient outcome to convince them to use our protocol more often. We will be looking at this in the coming months. (OF-92-179)

Weaning Protocol Evaluation In the Cardiovascular Recovery Room—Douglas G Sabau RRT, John S Sabo MS RRT. St Luke's Episcopal Hospital, *Houston, Texas.*

Study Question: Does a physician-approved therapist-driven weaning protocol decrease the length of time for postoperative mechanical ventilation? Through a collaborative effort between Respiratory Care, Nursing, and CV Anesthesia, a weaning protocol was developed and evaluated. The protocol defines eligibility, postoperative stages, and clinical interventions. **Method**: A pilot program was evaluated after 120 days to determine the effectiveness of protocol. Groups were determined by surgical procedures. Selected were coronary arterial bypass (CAB), aortic valve replacement (AVR), mitral valve replacement (MVR), and abdominal aortic aneurysm repair (AAA). Decision-making algorithms were prepared to ensure consistency of protocol implementation. Protocols analyzed cardiovascular status, ABGs, negative inspiratory force (NIF), and vital capacity. Mechanical ventilatory interventions include SIMV, CMV, pressure support, and flow-by. Evaluation of clinical outcome associated with protocol was accomplished by comparison of preprotocol and protocol populations. The preprotocol population consisted of 141 patients: Group 1—CAB (n = 94); Group 2—AVR (n = 16); Group 3—MVR (n = 19); and Group 4—AAA (n = 12). Protocol population (306 patients) consisted of Group 1—CAB (n = 254); Group 2—AVR (n = 21); Group 3—MVR (n = 10); and Group 4—AAA (n = 21). Reintubation rates within 24 hours were determined in protocol population. **Results:** Calculations were performed by formula (1) Average Intubation Time/Group = Total Intubation Hours/Group ÷ Total Patients/Group; (2) Average Total Intubation Time = Total Intubation Hours ÷ by Total Patients; (3) Percent Change = (Pre-Protocol Average Intubation – Protocol Intubation Time) ÷ Pre-Protocol Average Intubation Time. Analysis demonstrated mean (SD) values 0.73 (5.57) hour or 6.5% decrease of intubation time in Group 1; 1.91 (5.83) hours or 17.98% decrease in Group 2; 8.03 (3.86) hours or 41.17% decrease in Group 3; and 1.13 (5.25) hours or 11.87% decrease in Group 4. An average of 2.04 (6.61) hours or a 16.35% decrease in length of intubation in total patient population resulted. Only 2 patients were reintubated for reintubation rate of 0.006% (reintubated population ÷ total population). CAB group had a rate of 0.004% and AVR 4.7%. No reintubations occurred in the MVR or AAA groups. **Summary & Conclusion:** There has been a decrease in intubation time in this cardiovascular population. The pilot was determined a success and instituted as a standard protocol. There was concern about reintubations of AVR patients, and it was determined to monitor this population for reintubations. Subsequent analysis of 58 patients has shown an additional 3.69 hour (32.6%) decrease in intubation time with a reintubation rate of 0%. This has become a standard CQI monitor. 73% of our patients enter the protocol, and it is planned to expand on monitored outcome patients. (OF-92-191)

The Impact of a Postoperative Oxygen Therapy Protocol in Detecting Arterial Desaturation and on Determining Duration of Postoperative Oxygen Therapy—John J Komara Jr BA RRT, James K Stoller MD. The Cleveland Clinic Foundation, *Cleveland, Ohio.*

Despite the increasing popularity of pulse oximetry (POx) for monitoring oxygenation in various clinical settings, few studies have evaluated the impact and reliability of using POx in managing postoperative patients. In order to assess the clinical and financial impact of POx monitoring in immediate postoperative care in our center, the current study examines the efficacy of a postoperative oxygen (O_2) therapy protocol using a "stop criterion" of 92% saturation (measured on room air) as compared to prior standard practices in which decisions and criteria to stop O_2 therapy were made individually by anesthesia personnel. The current report examines retrospectively the experience of 40 nonconsecutive patients (20 protocol and 20 standard practice or nonprotocol patients) discharged from the Post-Anesthesia Care Unit to the regular nursing floor. Conventional guidelines suggest that postoperative O_2 therapy should be discontinued when a specified O_2 saturation is achieved and that failure to achieve this "stop criterion" results in continuation of both low-flow O_2 therapy and follow-up O_2

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saturation (S_{pO_2}) measurements until the "stop criterion" is met. Seventeen of 20 protocol patients (85%) satisfied the 92% stop criterion after 24 hours of low-flow O_2. The remaining 3 patients required continuation of low-flow O_2 for up to 72 hours. Subsequently, all 3 achieved a room air S_{pO_2} of 92% or greater. A total of 24 POx measurements was performed in these 20 protocol patients. Once discontinued from low-flow O_2, none of the protocol patients required reinstitution of O_2 therapy during their postoperative course. In contrast, in the nonprotocol group, only 4 of 20 patients (20%) achieved the stop criterion after 24 hours of low-flow O_2. Stop criteria before implementation of the protocol varied at the individual anesthesiologist's discretion (two 93%, five 94%, one 95%, twelve 96%); the mean S_{pO_2} for discontinuing O_2 therapy in the nonprotocol group was 95.2%. Consequently, the remaining 16 nonprotocol patients received O_2 for > 24 hours despite 12 of 16 patients (75%) satisfying a stop criterion of 92%. A total of 57 POx measurements was performed in the nonprotocol group. Three of 20 nonprotocol patients were discharged from the hospital without achieving their "stop criterion." Pulse oximetry charges ($2,793 vs $1,176) were 137% higher in the nonprotocol (previous standard practice) group as compared to the protocol group. Our results suggest that a formal O_2 therapy protocol assigning a stop criterion of 92% saturation for low-flow O_2 therapy in non-thoracic postoperative patients can be used safely while resulting in substantial cost savings and improved utilization of health care resources. (OF-92-175)

Common Devices and Techniques

Sound Levels of Humidifiers and Nebulizers Supplying Oxygen Hoods—Shelley C Mishoe MEd RRT, C Worth Brooks Jr BS RRT, Kim L Valeri MS RRT, Arthur A Taft MHS RRT. Medical College of Georgia, *Augusta, Georgia.*

Introduction: Clinical evidence indicates that the ear of the developing infant has a greater susceptibility to damaging effects of noise than the ear of an older child or adult. We sought to determine sound levels produced by various humidifiers and nebulizers supplying O_2 hoods in NICUs. **Materials & Method:** Sound levels were measured with Tracor RA110 sound level meter using the A-weighted scales. Background noise level was kept at a constant 45 dbA. Measurements were taken inside O_2 hood within an Isolette, with motor off. We studied 4 simple humidifiers: Aquapak 301, Dart 325 mL, MistyOx 500 mL, and Travenol; 3 heated humidifiers: Conchatherm III, Fisher & Paykel MR630, and Marquest SCT 2000; and 5 nebulizers: Aquapak 700 mL and 1000 mL, Dart 300 mL, MistyOx 500 mL and Travenol 1000 mL. 5 of each type were randomly selected for study. Equipment was studied at O_2 flowrates of 6, 8, 10, & 12 L/min under full, half-full, and empty water-reservoir conditions, using both Shiley and Peace O_2 hoods. Nebulizers were tested at F_{DO_2}s of 0.40, 0.60, and 1.00. Equipment was set up according to manufacturers' guidelines. **Results:** Data were analyzed using ANOVA, $\alpha = 0.05$. Results indicated significant main effects for F_{DO_2} ($p < 0.001$) and type of equipment ($p < 0.001$). Heated humidifiers were significantly quieter (× 48 dbA) than nebulizers (× 62 dbA). The Marquest Heated Humidifier was quietest (× 45 dbA) under all conditions, whereas the Aquapak 700 (× 73) and 1000 (× 71) were loudest. Heated humidifiers were quieter than simple humidifiers by as much as 10 dbA; with mean differences of 5-6 dbA. Water level did not have a significant effect on sound levels of humidifiers, but significantly affected nebulizers ($p < 0.001$). Sound levels for all but Aquapak nebulizers increased as water levels decreased. There was a significant interaction between equipment and hoods ($p < 0.001$), but sound levels were generally louder using Peace Hood. For heated humidifiers and Aquapak nebulizers, sound levels were louder with Shiley hood, but these differences were only ± 2 dbA. There was also a significant interaction between flowrate and equipment ($p < 0.001$). As flowrates increased, sound levels increased significantly for nebulizers and simple humidifiers, but remained relatively stable for heated humidifiers. **Conclusion:** Under various testing conditions, all humidifiers produced sound levels ≤ 58 dbA, maximum level recommended by the American Academy of Pediatrics, but all nebulizers exceeded this level. Results of this study and previous studies indicate that nebulizers used with O_2 hoods produce excessive noise and are not recommended for use in NICU. (OF-92-009)

Octave Band Analysis of Sound Level Frequencies and Intensities Produced by Nebulizers and Humidifiers—Shelley C Mishoe MEd RRT, C Worth Brooks Jr BS RRT, Kim L Valeri MS RRT. Medical College of Georgia, *Augusta, Georgia.*

Introduction: Degree of hearing loss resulting from noise exposure is related to intensity of sound, measured in decibels (db) and frequency of sound, measured in hertz (Hz). 1 Hz = 60 cycles/s. A decibel = 10 times the intensity-level logarithm. The human ear can perceive sound frequencies from 20 to 20,000 Hz and is more sensitive to damaging effects of high frequency sound > 4000 Hz. Broad-spectrum analysis commonly referred to as octave band analysis allows comparisons of sound intensities (db) and frequencies (Hz). We performed broad-spectrum analysis of humidifiers and nebulizers used in neonatal intensive care. Infants are at greatest risk for noise-induced hearing loss because of immaturity of organ of Corti and ototoxic effects of antibiotics. **Materials & Method:** We studied 4 simple humidifiers (Aquapak, Dart, MistyOx, Travenol), 3 heated humidifiers (Conchatherm III, Fisher & Paykel, Marquest), and 4 nebulizers (Aquapak, Dart, Travenol, MistyOx). Sound levels (db) were measured with a Tracor RA110 sound level meter at frequencies of 250, 500, 1000, 2000, 4000, and 8000 Hz. Measurements were taken at flowrates of 6, 8, 10, and 12 L/min under full, half-full, and empty water-level conditions using Peace and Shiley oxygen hoods. Nebulizers were tested at F_{DO_2}s of 0.40, 0.60, and 1.00. Background noise was kept constant at 45 dbA. Measurements were taken inside O_2 hood within an Isolette, without motor running. **Results:** Data were analyzed using ANOVA, $\alpha = 0.05$. Sound levels were significantly louder ($p < 0.001$) for neb-

ulizers compared to humidifiers. Type of equipment had a significant main effect ($p < 0.01$) on db at all frequencies, except 2000 Hz. Aquapak nebulizers were loudest with peak intensities (× 69) at 4000 and 8000 Hz. Maximum sound levels of humidifiers occurred at 250 Hz (× 51) and dropped off significantly after 1000 Hz. Nebulizers produced maximum sound levels at 4000 Hz (× 55). A 3-way interaction occurred ($p < 0.01$) between humidifiers, hood, and water level at 250 and 500 Hz and between humidifier, hood, and flow at 2000 Hz. There were no interactions for nebulizers, but significant main effects ($p < 0.01$) for nebulizer, water level, flow, and F_{DO_2} at each frequency. At frequency ≥ 2000 Hz, there was a significant main effect for hoods when using nebulizers. Overall, sound levels were generally louder across frequencies at higher flowrates and with Peace Hood. **Conclusions:** Hood can significantly affect sound intensity, especially at higher frequencies and should be a consideration in noise reduction. Heated humidifiers produced lowest sound intensities at lowest frequencies and are most appropriate for use in neonatal intensive care. (OF-92-014)

Evaluation of the Accuracy of Portable Peak Flowmeters—Mark Simmons MSEd RPFT RRT, Tiffany Zumbrum, Dean Hess MEd RRT. York College and York Hospital, *York, Pennsylvania.*

Introduction: Peak flowmeters are commonly used in the hospital and in the home to evaluate response to bronchodilator therapy. Purpose of study was to evaluate accuracy of 4 commercially available peak flowmeters. **Methods:** 4 peak flowmeter brands were evaluated (Pulmo-Graph, Pocket, Assess, and Mini-Wright). Four devices of each brand were evaluated, as supplied by manufacturer. Each device was evaluated new, and again after 200 uses, at an altitude of 150 m above sea level. We evaluated agreement between the peak flows measured by these devices and the peak flows simultaneously obtained, using a calibrated pneumotachometer (Cybermedic, Louisville CO). Each individual peak flowmeter was evaluated using 5 peak flow maneuvers generated randomly at 3 flow ranges (low: < 250 L/min, medium: 250-500 L/min, high: > 500 L/min). Peak flow maneuvers were generated by 2 healthy subjects over range of 80-780 L/min by varying effort, and with use of in-line resistors. Methodology used in this study was similar to that used in a previously published evaluation of peak flowmeter accuracy (Chest 1991;99:358). Statistical analysis consisted of calculations of mean (SD), ANOVA, and bias and precision analysis. **Results:** There was a significant difference in bias between 4 peak flowmeter brands ($p < 0.001$). Bias changed after 200 uses for Assess ($p = 0.046$) and for Pulmo-Graph ($p < 0.001$), but not for Wright ($p = 0.558$) or for Pocket ($p = 0.267$). There was also a significant difference in bias between 4 units tested for each brand ($p < 0.01$ in each case). Assess produced flows less than pneumotachometer at low and medium flows but was accurate at high flows. Mini-Wright produced flows > pneumotachometer at low flows, < pneumotachometer at high flows, and was accurate at medium flows. Pulmo-Graph produced flows < pneumotachometer at high flows, and was accurate at low and medium flows. Pocket was accurate over entire flow range. **Conclusions:** Because there were differences in the accuracy of peak flowmeter brands that we evaluated, we recommend that the same device always be used when measuring serial peak flows on patients. Because design of this study did not allow evaluation of the reproducibility of the measurements, we recommend that further studies be conducted to evaluate performance of these devices. (OF-92-047)

A Comparison of Modern Stethoscope Frequency Response Curves—Jonathan B Waugh MS RRT, Crystal L Dunlevy EdD RRT. The Ohio State University, *Columbus, Ohio.*

Although stethoscopes are used daily for collecting important patient cardiopulmonary information, many practitioners are influenced in their choice of a stethoscope by its appearance or by features that make the instrument easy to use or convenient to carry rather than by its inherent worth as an acoustic instrument. **Method & Materials:** We performed objective bench measurements of 5 modern stethoscopes. We measured the sound level over a frequency range of 30 to 3,000 Hz (dividing the range into three groups of low, 30-120 Hz; medium, 150-1,300 Hz; and high, 1,300-3,000 Hz) through stethoscopes ranging in price from $46.95 to $180 (Littman: Cardiology II 17″ tubing $145, Master Cardiology 16″ $180, Classic II 19″ $65; Hewlett Packard: Model 280 24″ $138; McCoy: Discrimatone 16″ $46.95). Because one of the stethoscopes had only a diaphragm chestpiece, all measurements were made through each stethoscope's diaphragm. A precision sound-level meter (Brüel & Kjaer DK-2850) and a Telephonics TDH-50P headphone were used in conjunction with a WaveTek sweep generator to produce and measure sounds heard through stethoscopes. An experienced engineer from a university speech & hearing laboratory was enlisted as an expert advisor to guide the selection of measurement equipment and the data collection process. **Results:** Analysis by repeated measures ANOVA showed the main effects for frequency and stethoscope brand to be significantly variable across each third of the 30-3,000 Hz range. The interaction effect was that as frequencies increased from 150 through 1,300 Hz, means for the Hewlett-Packard, Master Cardiology, and Cardiology II remained comparatively constant, but the means for the Classic II and McCoy decreased. **Conclusions:** There was no significant difference between the two top performing stethoscopes, the Hewlett-Packard and the Littmann Cardiology II, which out-performed even the most expensive instrument, the Littmann Master Cardiology, but the other three instruments had considerable variations in performance depending upon the frequency range of interest. The stethoscopes as a group were more accurate in the middle-to-high frequencies. The less expensive scopes (Discrimatone and Classic II) might be used satisfactorily for listening to low tones [eg, low (presystolic, basal, and mitral diastolic murmurs) and 1st, 2nd, & 3rd heart sounds and gallop rhythms, 20-115 Hz] and some medium &

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high heart sounds but would be poor choices for listening to most breath sounds [bronchial 240-1,000 Hz; vesicular 150-1,000 Hz; tracheal, bronchial, bronchiolar > 800 Hz; crepitations ≥ 750 Hz]. (OF-92-061)

A Comparison of Measured Total Energy Expenditure to Measured Resting Energy Expenditure—Marcia S Kemper BA CRTT, Pedro Beredijiklian MD, Allen Hyman MD, Charles Weissman MD. Columbia University, *New York, New York.*

Determining a patient's measured resting energy expenditure (MREE) assists in designing nutritional regimens. The caloric needs of surgical ICU patients has been defined as 1.2 times MREE. The additional 20% above MREE is 5% for activity and 15% for day-to-day variability. We wanted to compare the accuracy of adding 20% to the MREE to the actual measured daily total energy expenditure (TEE). **Methods:** 6 post-operative, ventilator-dependent patients were studied for 49 days. TEE was measured with a validated and calibrated Puritan-Bennett 7250 metabolic monitor, which was interfaced according to manufacturer's specifications. The P-B 7250 is able to continuously measure $\dot{V}_{O_2}$ and $\dot{V}_{CO_2}$ and report the average of the previous 24 hours.This was used to calculate TEE. We calculated the daily resting energy expenditure using $\dot{V}_{O_2}$ and $\dot{V}_{CO_2}$ measurements from resting periods. An additional 20% was added to MREE values and 15% to TEE values, as TEE includes activity but not day-to-day variability. **Results:**

Patient	TEE	TEE + 15%	MREE	MREE + 20%
1	1410 (178)*	1621 (204)	1345 (144)	1618 (175)
2	1857 (34)	2136 (40)	1840 (67)	2208 (80)
3	1982 (87)	2280 (100)	1889 (52)	2268 (60)
4	2365 (32)	2720 (37)	2535 (41)	3042 (49)
5	991 (25)	1139 (29)	987 (14)	1185 (17)
6	1541 (52)	1772 (60)	1573 (60)	1894 (68)

* Values are mean (SD) kcal/day.

The MREE was within ±6% of TEE, and MREE + 20% was within ±10% of TEE + 15%, using the Puritan-Bennett 7250. **Conclusion:** When designing a nutritional program, either MREE + 20% or TEE + 15% may be used to calculate caloric requirements because there is good agreement between the two methods. (OF-92-098)

The Effect of Hemoglobin Level on Single-Breath Carbon Monoxide Diffusing Capacity in Chronic Hemodialysis Patients—Charles McArthur BA RPFT RRT, Michael J Path CRTT CPFT, Paul A Abraham MD, Scott F Davies MD. Hennepin County Medical Center and The University of Minnesota, *Minneapolis, Minnesota.*

We studied the effect of recombinant human erythropoetin (r-HuEPO) therapy on D_{LCO} in patients on chronic hemodialysis (CHD). Reduced D_{LCO} has been reported in uremic patients on CHD, and has been shown to persist even after application of corrections for the anemia seen in these patients. We studied the change in D_{LCO} after r-HuEPO therapy to evaluate the appropriateness of applying standard corrections for Hb to D_{LCO} in CHD patients. **Methods:** 6 patients undergoing hemodialysis and without evidence of cardiopulmonary disease by history, physical exam, chest x-ray, or echocardiography were selected for study. PFTs including spirometry, lung volumes, and D_{LCO} were performed on a Medical Graphics system 1070 (Medical Graphics Corp, St Paul MN). The D_{LCO} measurement utilized a gas chromatograph and met all recommendations of the ATS Statement on D_{LCO}. Breath-hold time was measured using the Jones-Meade method. Hb levels were measured by the cyanmethemoglobin method (Coulter Diagnostics, Hialeah FL). On completion of baseline measurements, each patient received 100 IU/kg of r-HuEPO after each dialysis 3 times/week for 12 weeks. All measurements were repeated at the end of the 12-week period. Pre- and post-drug measurements were all done 24 hours after HD. **Results:** A paired *t* test with two tails was used to compare measurements pre- and post-drug. Standard corrections were applied and compared to the measured change in D_{LCO} in the same fashion. There was no statistically significant difference between measured D_{LCO} and D_{LCO} adjusted with standard corrections.

	Pre-Drug	Post-Drug	p Value
FEV_1% (% pred)	86.5 (4.4)	86.2 (5.3)	ns
FVC (% pred)	104.2 (8.1)	105.6 (10.1)	ns
VA (% pred)	94.3 (9.2)	95.5 (5.4)	ns
D_{LCO} (% pred)	55.7 (11.5)	84.2 (20.4)	p = < 0.005
Hb	6.7 (0.6)	12.1 (1.8)	p = 0.001
D_{LCO} (means)	16.76 (3.2)	25.48 (7.3)	p = < 0.05

Post-Drug D_{LCO} vs Predicted D_{LCO} by Adjustment Methods

Method	Mean Difference	95% CI	p Value
Cotes	–1.8	–4.9 to 1.3	ns
Burgess	–0.7	–3.0 to 2.7	ns

Conclusion: Standard techniques to adjust D_{LCO} for anemia provide adequate estimations in CHD patient with normal PFTs. (OF-92-107)

Humidification of 10 Adult Patients Undergoing Mechanical Ventilation by the Life Design Systems (LDS) Humidi-Flo Humidifier and Dual Heated-Wire Circuit—Russell T Reid RCP, Kent Mercer RCP. UC-Davis Medical Center, *Sacramento, California.*

Little information is available concerning level of humidity delivered to patients by latest-generation humidifiers capable of utilizing dual heated-wire ventilator circuits. Many of these humidifiers have a relative humidity control adjustable between 70-100%, raising further concerns about adequacy of humidification when control is set at 70%. **Methods:** 10 patients mechanically ventilated on Siemens Servo 900C ventilators were placed on LDS Humidi-Flo dual servo model 17000 humidifier, 60" dual heated-wire circuit (Model #817661), and high flow humidifying chamber (Model #17010). A humidity cham-

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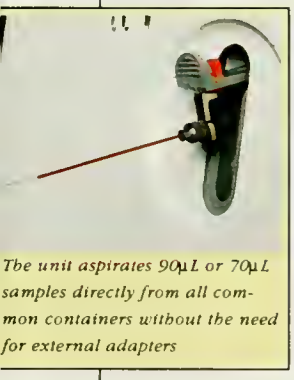

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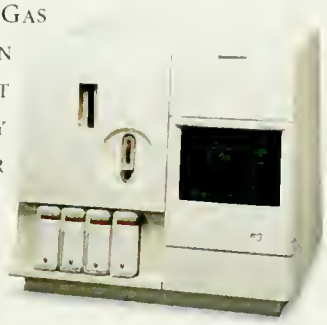

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ber (HC) was constructed to accommodate the probe of a capacitance-type digital hygrometer (Curtin-Matheson Scientific Model #244-355) and allow inspiratory gas to pass through chamber for measurement. The HC, containing hygrometer probe, was heated to mean (SD) 39.2°C (0.24) and placed in inspiratory limb of ventilator circuit every 4 hours for 1 minute. Measurements were recorded for both mechanical and spontaneous breaths where applicable. A thermocouple thermometer (Cole Palmer, Model #L08500-40) continuously displayed temperature from 3 areas within ventilator circuit (1) adjacent to LDS humidifier-chamber temperature probe, (2) adjacent to humidifier temperature probe on inspiratory side of patient Y, and (3) at proximal airway connection of Y. The LDS humidifier temperature control was set at 37°C for all patients; however, proximal airway temperature measurement in table below was 3" closer to patient relative to placement of temperature probe from the LDS humidifier. Measurements were taken in stable patients from medical and surgical populations for 48 hours unless patient was extubated sooner. **Results:**

Patient	Ventilator Mode	Type of Breath	Relative Humidity % (SD)	Absolute Humidity	Proximal Temperature (SD)
1	A/C	Mechanical	84.8 (9.6)	34.7 (4.5)	35.7 (0.4)
2	A/C	Mechanical	87.1 (4.6)	33.1 (1.8)	34.0 (0.4)
3	A/C	Mechanical	95.7 (6.9)	40.0 (7.7)	32.7 (0.6)
4	A/C	Mechanical	81.2 (8.5)	31.8 (3.3)	34.4 (1.0)
5	SIMV + PS	Mechanical	77.7 (6.2)	30.5 (2.4)	34.4 (1.9)
5	SIMV + PS	Spontaneous	76.8 (7.0)	30.0 (2.6)	34.1 (2.5)
6	SIMV + PS	Mechanical	97.2 (3.2)	39.1 (4.9)	33.2 (0.3)
6	SIMV + PS	Spontaneous	97.4 (3.6)	39.1 (5.8)	33.0 (0.2)
7	SIMV + PS	Mechanical	87.2 (8.5)	32.7 (2.3)	32.9 (2.0)
7	SIMV + PS	Spontaneous	87.3 (9.2)	31.8 (2.0)	32.4 (2.3)
8	SIMV + PS	Mechanical	84.6 (3.3)	33.2 (1.8)	34.9 (0.8)
8	SIMV + PS	Spontaneous	87.6 (1.1)	35.0 (2.1)	35.0 (0.8)
9	SIMV	Mechanical	79.7 (7.3)	31.0 (2.4)	34.4 (0.5)
9	SIMV	Spontaneous	78.7 (9.4)	30.6 (3.3)	34.4 (0.7)
10	PS	Spontaneous	87.9 (6.1)	35.0 (5.6)	35.1 (0.2)

Conclusion: All patients receiving humidification using LDS system met or exceeded ANSI standard of 30 mg H_2O/L for a heated humidifier. Standard was met while measurements were made under clinical conditions with humidity control on LDS set to deliver 70% relative humidity. (OF-92-110)

The Effect of Time on Breathing Circuit Compliance—Thomas V Hill MS RRT, Kettering College of Medical Arts, *Kettering, Ohio*; Kim L Valeri MS RRT, Arthur A Taft MHS RRT, Shelley C Mishoe MEd RRT, Cynthia J Phillips BS RRT, Medical College of Georgia, *Augusta, Georgia.*

Introduction: Some microprocessor-controlled ventilators correct gas volume delivered to the patient to compensate for volume lost due to compliance of the breathing circuit (CBC). Because CBC is usually calculated only when the circuit is initially placed in use, changes in CBC with time may result in inaccurate correction of delivered tidal volume. The purpose of this study was to determine whether CBC changed with time. **Method:** We measured compliance of 3 different types of breathing circuits (BC) attached to a Bennett MA2+2 set at V_T = 1.0 L, f = 12/min, $\dot{V}$ = 60 L/min, F_{IO_2} = 0.21. After initial measurement of compliance, BC were heated to 34°C inside an Isolette and connected to a test lung for 48 hours. Compliance of test lung was adjusted so that peak inspiratory pressure was 50 cm H_2O. 5 samples of each BC were tested. CBC was measured at 1, 3, 6, 12, 24, and 48 hours by injecting air from a calibration syringe into BC (with all ports capped) until pressure reached 100 cm H_2O. The exhalation valve was opened, and released volume was measured with an RT-200 calibration analyzer. **Results:** Data were analyzed using a one-way ANOVA and two-tailed *t* test. Level of significance was set at 0.05. There was no significant difference in CBC of the Hudson Ethylene Vinyl Acetate (EVA) Circuit [mean (SD)] 1.50 (0.08) mL/cm H_2O, $p = 0.26$, and Puritan-Bennett Polyethylene Circuit 1.47 (0.06) mL/cm H_2O, $p = 0.24$, over 48 hours. CBC increased from 2.31 (0.06) mL/cm H_2O to 2.52 (0.06) mL/cm H_2O during first hour in the Hudson Kraton Circuit, and difference was significant ($p < 0.001$); there was no significant difference after 1-hour measurement ($p = 0.67$). **Conclusions:** CBC did not change significantly for Hudson PVC and Puritan-Bennett Polyethylene Circuits. For periods up to 48 hours, it may not be necessary to recalculate CBC for purpose of correction of delivered tidal volume. Difference seen in first hour in the Hudson Kraton circuit may be due to heating circuit and not to any changes occurring over time. Although this difference may not be clinically important, it may be useful to calculate CBC after Hudson Kraton circuit has reached operation temperature. (OF-92-115)

An Evaluation of the Physiological Effectiveness of Hand-Held Ultrasonic Nebulizers as Opposed to Continuously Run Pneumatic Nebulizers—James W Taylor MA RRT, Kalamazoo Valley Community College; Geoffrey R Grambau MD, Margaret Shoemaker BS RRT, Mark Durren BS, Bronson Methodist Hospital; Michael R Stoline PhD, Western Michigan University; Ilsoon Yang, Michigan State, Kalamazoo Center for Medical Studies—*Kalamazoo, Michigan.*

We compared a hand-held ultrasonic nebulizer (MicroStat) to conventional pneumatic nebulizers (updraft) in 17 acutely ill hospitalized patients. Entrance criteria included flows < 80% of predicted on pulmonary function testing. A randomized entry and crossover repeated measurement design was used with each patient serving as his own control. Treatments were given with a unit dose of 2.5 mg of albuterol diluted with saline, to a total volume of 3 mL (updraft) or 2.5 mg of albuterol diluted with 0.5 mL of normal saline. Updraft devices were run at 7 L/min and were terminated once the medication was delivered. Ultrasonic nebulization was performed during a total of 10 breaths. Pulmonary function testing was performed post-treatment at intervals of 20, 60, and 240 minutes. **Results:** There was no significant difference for the changes produced by the 2 devices at 20, 60, and 240 minutes in FVC 0.4834, 0.5402, 0.3887; FEV_1 0.1005, 0.4639, 0.3475; FEF_{25-75} 0.2855, 0.6902, 0.5155; or peak flow 0.5334, 0.2897, 0.1819 resulting from administration of albuterol by the two devices. Treatment

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times ranged from 10-12 minutes for the updraft aerosols and 5-6 minutes for the ultrasonic nebulizer. General trends demonstrated a larger change score for the updraft devices as compared to the ultrasonic nebulizer. **Conclusions:** Pulmonary function test results suggest that comparable amounts of respirable bronchodilator aerosol are delivered under the conditions described. (OF-92-119)

Evaluation of the MistyOx Gas Injection Nebulizer—Richard Hoskins CPFT RRT, John S Sabo MS RRT, Joy E Hargett BS RRT, Elizabeth Bearden AAS RRT. St Luke's Episcopal Hospital, *Houston, Texas.*

Study Question: Does the MistyOx Gas Injection Nebulizer (GIN) provide accurate high F_{IO_2}s at high flowrates? The GIN is designed to provide a high gas flow to the patient with accurate F_{IO_2}s at elevated levels, utilizing a primary (1°) and secondary (2°) gas source, either of which may be oxygen or air. **Method:** Using an RT-200 Calibration analyzer and Teledyne TED 200 O_2 analyzer calibrated per manufacturers' recommendations, we evaluated flow and F_{IO_2} capabilities of the GIN and of the Baxter Travenol large volume nebulizer (LVN). **Results:**

O_2 1° Gas Source Setting	Air 2° Gas Source Setting	F_{IO_2}	Total Flow (L/min)
Maximum	0	1.0	42.1
15	15	0.61	30
Maximum	Maximum	0.45	133.70
0	Maximum	0.21	91.2

Air 1° Gas Source Setting	O_2 2° Gas Source Setting	F_{IO_2}	Total Flow (L/min)
Maximum	0	0.21	142
15	15	0.59	30
Maximum	Maximum	0.75	134.2
0	Maximum	1.00	91.2

The highest achievable flowrate of the LVN was 49.5 L/min at an F_{IO_2} of 0.28. A setting of 1.0 produced a flowrate of 14.8 L/min. **Conclusion:** The GIN provides accurate F_{IO_2}s at high flowrates and may be a valuable alternative in providing O_2 to patients with high inspiratory demands. (OF-92-128)

Are All Spacer Devices Equally Effective?—Brian L Smith RRT, Frank J Caruso RRT, University Hospitals of Cleveland; Jean L Arnold BSEP, Kingman P Strohl MD, E Chandler Deal MD, Case Western Reserve University—*Cleveland, Ohio.*

Purpose: We compared the performance of 3 spacer devices: InspirEase (In), Aerochamber (Ae), and a Prototype spacer (PS) that utilizes the Airlife Metered Dose Inhaler Dispenser in conjunction with a variation of the Airlife Ventilator Monitoring Adapter flex tube and 1-way valve system. **Methods:** Known asthmatic patients (n = 22) on stable medications and in absence of acute exacerbation were randomly assigned to use 1 of the 3 spacer devices. Patients had not received aerosol bronchodilator therapy for at least 4 hours prior to the protocol. Spirometry was performed to ATS standards on each patient before and 10-15 minutes after 2 puffs of isoetharine via Bronkometer, which was delivered using the assigned spacer. **Results:** FVC was not significantly different; however, in the three groups, a significant change occurred in FEV_1 with challenge: percent change [mean (SD) In + 23 (7) %; Ae + 14 (7) %; PS + 15.0 (8) %]. Significant differences were found between In and Ae ($p = 0.0332$) and between In and PS ($p = 0.0276$) but no difference between PS and Ae ($p = 0.4003$). **Conclusion:** The In was found to provide greater bronchodilation than either Ae or PS. We speculate that the difference in effect resulted from greater aerosol delivery with the In because the technique requires patients to perform two inspiratory manuevers and results in rebreathing of aerosol medications. This differs from the Ae and PS, which require patient to perform only one inspiratory manuever. Further studies are planned to determine whether more medication delivered through the Ae and PS or alternation of technique improve spacer performance. (OF-92-157)

Small Volume Nebulizer Use with Mask CPAP: A Bench Study—William W Quinn RPFT RRT, Alton Ochsner Medical Foundation, *New Orleans, Louisiana.*

I observed therapists placing nebulizers containing bronchodilators in-line with high-flow mask CPAP. I sought to demonstrate to them what I hypothesized to be the ineffectiveness of this technique. I also wanted to determine whether an effective alteration of the circuit configuration could be made. **Method**: A 2-chambered TTL was used to simulate spontaneous breathing by locking the sides together and driving one side with a ventilator; the other side was hooked to the neck of a head from a resuscitation dummy, and the various CPAP devices were attached to the head. Nebulized food coloring was used as a tracer, and a filter placed in a trap position in the TTL changed color according to how much coloring was deposited there. A jury scored the filters against a visual color scale to obtain the results. Four CPAP methods were tested, all with 10 cm H_2O CPAP and the nebulizer operated at 7 L/min: (1) nebulizer in-line with 75 L/min CPAP flow; (2) nebulizer in-line with 30 L/min CPAP flow; (3) nebulizer in-line with 15 L/min CPAP flow; and (4) nebulizer attached to a specially configured CPAP mask, where 75 L/min inspiratory and expiratory flow were routed through a separate port from the nebulizer. Also, a fifth method was tried as a control: direct administration with an aerosol mask. **Results**: Mean (SD) color scores (n = 5) were (1) 2.4 (0.49), (2) 6.8 (0.4), (3) 11.6 (0.49), (4) 17.6 (1.02), and (5) 17.2 (1.17). **Conclusions:** Even when CPAP flow is dropped, placing a treatment nebulizer in-line with mask CPAP offers the patient significantly less ($p < 0.0001$) medication than placement either on the modified CPAP mask or on an aerosol mask. (OF-92-180)

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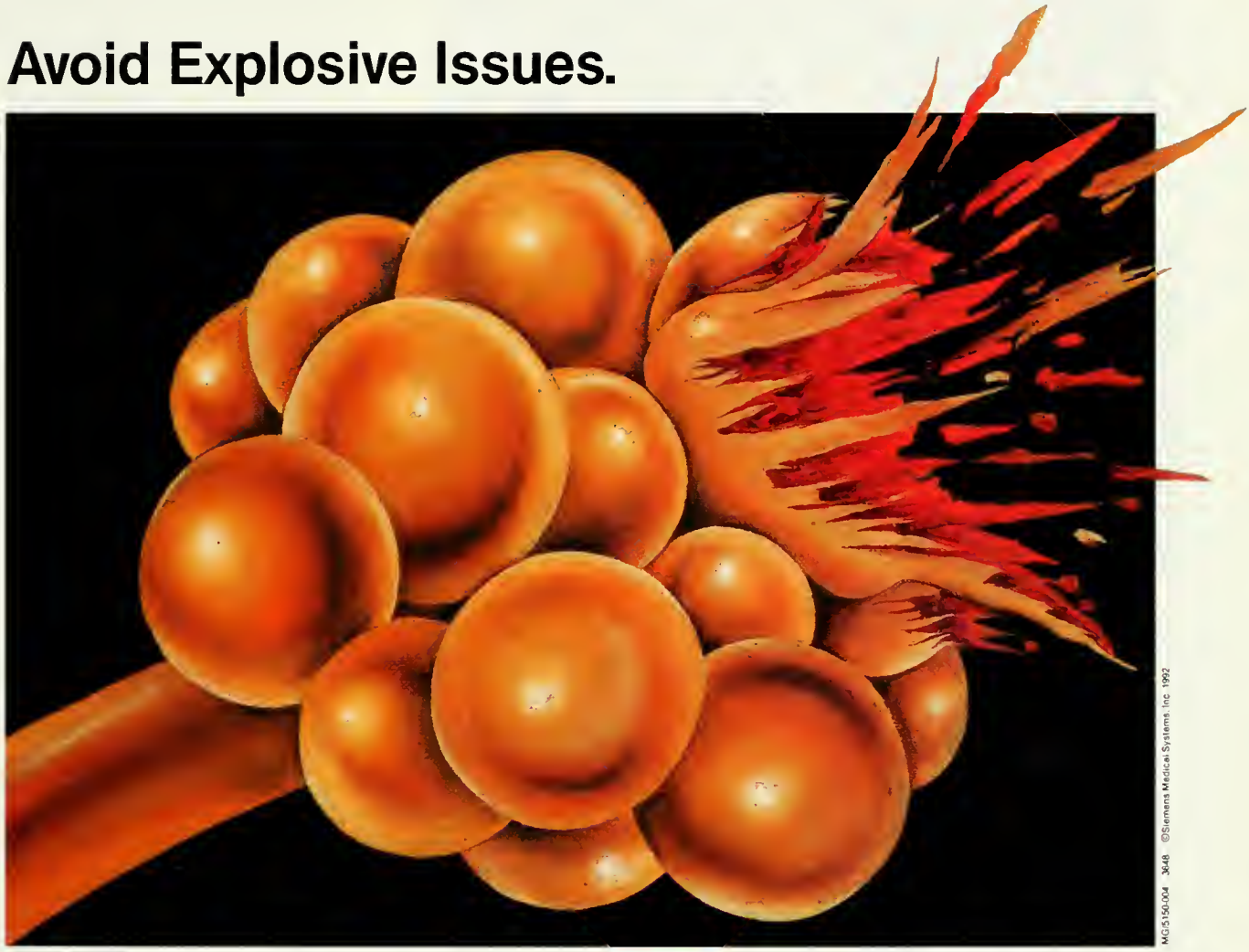

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MistyOx 441H in lieu of Doubled-Flow nebulizers: A Bench Study—William W Quinn RPFT RRT, Alton Ochsner Medical Foundation, *New Orleans, Louisiana.*

I sought to confirm the adequacy of the new MistyOx 441H nebulizer (MON) to deliver F_{IO_2}s of 0.60, 0.80, and 0.95 without doubling nebulizers (DN). **Method**: A 2-chambered TTL was used to simulate spontaneous breathing by locking the sides together and driving one side with a ventilator; the other side was hooked to the head of a resuscitation dummy wearing an aerosol face mask. Respiratory rates (RR) of 20, 25, 30, 35, and 40 were generated at tidal volumes (V_T) of 200, 300, 400, 500, and 600 mL. Flow was adjusted to maintain a 1:2 I:E with a sine wave from a 7200 ventilator. I obtained O_2 readings with analyzer in a simulated alveolar position while F_{IO_2}s of 0.60, 0.80, and 0.95 were administered using both MON and DN (Automatic Liquid Packaging ALP 1612). I obtained two series of data using both devices. **Results:** Simulated alveolar O_2s for all RR for a given V_T are grouped together; values are mean (SD), n = 10.

	0.60 F_{IO_2}		0.80 F_{IO_2}		0.95 F_{IO_2}	
V_T	MON	DN	MON	DN	MON	DN
200	0.61 (0.0)	0.61 (0.0)	0.80 (0.0)	0.76 (0.4)	0.93 (0.5)	0.84 (1.6)
300	0.61 (0.0)	0.61 (0.4)	0.78 (1.4)	0.74 (1.4)	0.91 (1.0)	0.79 (1.4)
400	0.60 (1.1)	0.60 (0.9)	0.76 (0.5)	0.70 (1.9)	0.88 (1.7)	0.77 (2.6)
500	0.58 (2.2)	0.59 (1.9)	0.74 (1.9)	0.66 (2.6)	0.83 (2.6)	0.70 (3.3)
600	0.54 (3.9)	0.56 (2.8)	0.70 (3.0)	0.61 (4.0)	0.79 (3.8)	0.65 (3.1)

Experience: The single MON yields less condensation, fewer fluctuations in delivered F_{IO_2}, less noise, and a $5.84 savings per patient day compared to DN. With either modality, hyperpnea and/or tachypnea may still require additional flow. **Conclusion:** There is no significant difference between the F_{IO_2} efficacy of the MON and DN at an F_{IO_2} of 0.60, but at 0.80 and 0.95 the MON administers significantly ($p < 0.0001$) higher F_{IO_2} to the simulated alveolar position than the DN, although neither attains the desired concentration at $V_T > 400$ mL and concentrations > 0.60. (OF-92-182)

Sound Level Comparison between UHC-Qualified-Vendor Prefilled Nebulizers—Brian Clark RRT, Lila Nash, Donna Jackson, Marilyn Parker, Gary Gradwell BS RRT, Sean Weckerly, Dorisanne D Miller RRT, Herbert Patrick MD, Thomas Jefferson University Hospital, *Philadelphia, Pennsylvania.*

While our department evaluated two prefilled nebulizers, Baxter 2D0808 nebulizer kit and Hudson Aquapak, Cat. No. 031-28(028), several patients complained about the sound level of the Hudson nebulizer. These complaints led to the evaluation of the decibel [dB(A)] level produced by these nebulizers. The nebulizers were tested in the laboratory with a background noise level of 37 dB(A). Five nebulizers of each brand were tested, each at 98-100%, 40%, and 28% settings. A pressure-compensated Precision Medical Oxygen Flowmeter Model 1MFA1001 was used with the flow turned to flush (> 12 L/min). The sound level was measured 3 feet from the nebulizer output, using a Brüel & Kjaer Model 2232 Sound Meter. Two calibrated Catalyst Research MiniOx III Oxygen monitors were used to verify F_{IO_2} settings. To provide a relationship to background sound levels in our hospital, 9 general patient rooms and 9 ICU rooms were measured at mean (SD) levels of 51.7 (0.7) dB(A) and 57.5 (1.6) dB(A), respectively. OSHA regulations limit sound to 90 dB(A) over an 8-hour period. **Results**:

Sound Level in dB(A), Mean (SD)

	F_{IO_2} Settings		
	0.98-1.0	0.40	0.28
Baxter 2D0808	53.4 (1.5)*	64.5 (1.9)*	78.9 (2.4)*
Hudson Aquapak 031-28(028)	71.1 (2.4)†	70.4 (3.3)	78.3 (3.5)

†$p < 0.05$, *t* test difference by nebulizer.

*$p < 0.05$, *t* test difference by F_{IO_2}.

At the 0.28 F_{IO_2} setting, the flow can be decreased to 5 L/min, reducing the sound level in both the Baxter and the Hudson nebulizer to 55.5 (1.8) and 60.3 (6.5), respectively. The Hudson produced more sound than the Baxter at F_{IO_2} 0.98-1.0, but at the lower F_{IO_2}s there was no statistical difference. Because patient complaints about the sound level of the Hudson nebulizer included lower F_{IO_2} settings, it may be that the nebulizer sound spectrum is as important as objective decibel measurements. (OF-92-185)

Small Volume Nebulizer Use with Higher F_{IO_2}: A Bench Study—William W Quinn RPFT RRT, Alton Ochsner Medical Foundation, *New Orleans, Louisiana.*

I observed therapists placing small volume nebulizers (SVN) containing bronchodilators in line with double-flow large volume nebulizers (LVN) leading to an aerosol face mask (AFM). I sought to demonstrate to them what I hypothesized to be the ineffectiveness of this technique in giving medication, and I also wanted to determine whether an alteration of circuit configuration could be made that would maintain high F_{IO_2} without decreasing medication delivery. **Methods**: A 2-chambered TTL was used to simulate spontaneous breathing by locking the sides together and driving one side with a ventilator; the other side was hooked to the neck of a head from a resuscitation dummy wearing an AFM. Nebulized food coloring was used as a tracer, and a filter placed in a trap position in TTL changed color according to how much coloring was deposited there. A jury scored filters against a visual color scale to obtain the results. Three methods were tested, all with an F_{IO_2} of 0.8 from doubled LVN and SVN operated at 7 L/min: Method 1—SVN in-line with LVN flow to AFM; Method 2—SVN adapted through side port (SP) of AFM receiving LVN flow through main port (MP); Method 3—SVN on MP with LVN flow adapted through SP. Also, a fourth method was tried as a control: SVN on MP with no LVNs present. **Results:** Mean (SD) color scores (n = 5) were as follows: Method 1—6.0 (1.1); Method 2—7.6 (0.5); Method 3—15.8 (1.2); and Method 4—17.2 (1.2). **Conclusions**: Placing an SVN in-line

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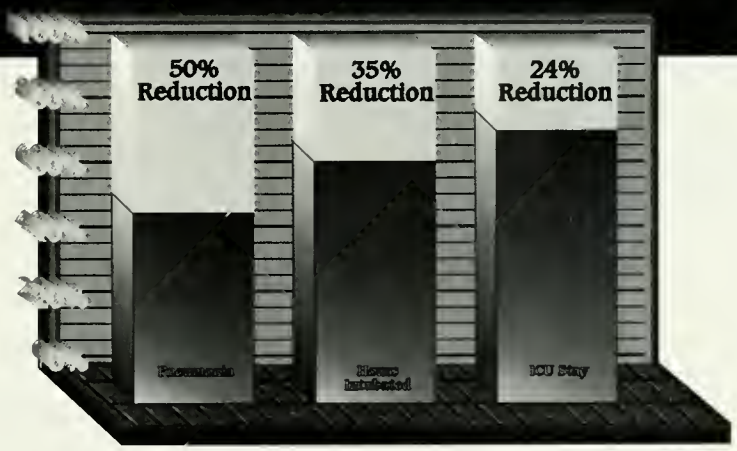

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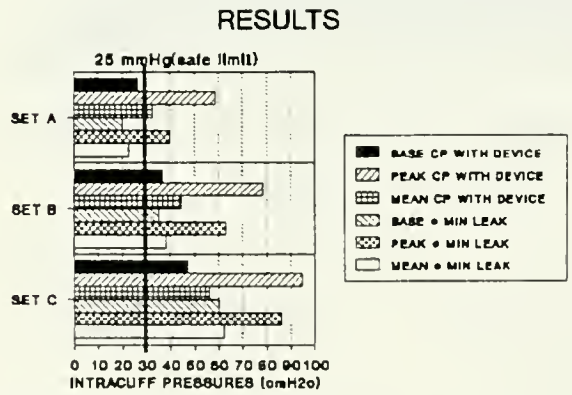
or in SP with doubled LVNs leading to MP of AFM offers patient significantly less ($p < 0.0001$) medication than placement on MP with or without additional flow added through SP to assure a continued high F_{IO_2}. (OF-92-194)

Airway Management & Resuscitation

Tracheal Injury: Can We Prevent It? PressurEasy vs Minimum Leak—Jacob C Koens Jr RRT, Paul B Blanch BA RRT. Shands Hospital. *Gainesville, Florida.*

Severe tracheal injury is a complication of endotracheal intubation with mechanical ventilation. This injury may occur at intracuff pressures (CP) as low as 25 torr. We tested and compared 2 methods used to prevent this injury: (1) minimum leak, described as maintaining cuff volume to allow a leak of not more than 10% of delivered V_T and (2) the Respironics PressurEasy using manufacturer's guidelines. The PressurEasy device is a cuff pressure regulator that uses an airway-biased, spring-loaded diaphragm to maintain CP. By attaching PressurEasy to ventilator circuit via a small plastic tube, increasing pressure from circuit acts upon diaphragm to raise and lower CP with circuit pressure. Both methods were evaluated using an adult Imatrach trachea model (Mallinckrodt) attached to a lung model (Michigan Instruments TTL) ventilated through an 8.0-mm endotracheal tube at three support levels: A. CPAP 0 cm H_2O, PIP 40 cm H_2O; B. CPAP 10 cm H_2O, PIP 60 cm H_2O; and C. CPAP 20 cm H_2O, PIP 80 cm H_2O. Rate was maintained at 10 bpm, V_T 1.0 L, inspiratory time 1.5 seconds with a decelerating inspiratory flow pattern. PIP was varied by changing lung compliance. CP was measured by inserting a 20-gauge blunt needle into the cuff through the pilot tube channel of tube, distal to cuff. System was then tested for leaks and attached to a calibrated strip-chart recorder (Pneumogard, Novametrix). Five PressurEasy devices from three lots were tested, minimum leak technique was also evaluated five times at each support level. Means and standard deviations were calculated for each group.



PressurEasy did not provide protection for trachea when used with mechanical ventilation and CPAP. Minimum leak technique also failed to maintain CP within a 'safe' range during ventilation with high CPAP and PIP pressures. Although we only measured intracuff pressures, a previous study has demonstrated a high correlation between intracuff pressure and amount of pressure exerted on tracheal wall (Chest 1985;87: 720). Information like ours may lead to a new technique that will reduce the incidence of tracheal damage. (OF-92-004)

Reversal of Acute Dyspnea and Hyperemia following Bypass of Tracheal Granulation with a Custom-Made, Hybrid Tracheostomy Tube—Charles J Gutierrez MS RRT, Jose E Perez MD, Lee Trugillo CRNA, David Baldree RRT. James A Haley Veterans' Hospital and University of South Florida College of Medicine, *Tampa, Florida.*

Introduction: Chronic airway obstruction is a common complication of intubation and tracheostomy. Fiberoptic bronchoscopy of a ventilator-dependent, C-4 quadriplegic revealed a 75% subglottic occlusion of tracheal lumen secondary to granulation tissue on inner anterior tracheal wall, and a 50% substomal occlusion secondary to granulation tissue on inner posterior tracheal wall. In spite of 3 separate sessions of laser photocoagulation, patient exhibited recurrent, paroxysmal episodes of refractory dyspnea, hypoxemia, and tracheal pain, secondary to resurgence of granulation tissue. Such episodes were difficult to manage with commercially available tracheostomy tubes (TTs) because their short length made it impossible to bypass regions obstructed by granulation tissue. **Methods & Materials:** Recannulation of stoma with a custom-made hybrid TT improved ventilation and rapidly resolved dyspnea and hypoxemia. The hybrid TT was made from an 8-mm-ID (Sheridan 5-10316) cuffed endotracheal tube (ETT) cut at 14 cm and stabilized on neck with a flange cut from a 8-mm-ID (Bivona 850090/MF1690) TT. To ensure optimal grip of the ETT by the flange, the internal diameter (ID) of both flange and ETT were equal. **Results:** Successful bypass of granulation tissue by the Bivona-Sheridan hybrid TT was confirmed bronchoscopically. Roentgenograms revealed hybrid TT remained in proper position, several weeks after cannulation. Following initial experience, upper airway problems in additional patients (n = 4) with tracheostomies were successfully managed using a hybrid TT. A flange, cut from a Bivona TT and slipped over adapter end of a standard ETT, appears to successfully prevent undesired migration of tube, yet allows tube to be repositioned, relative to the flange, as warranted by distorted tracheal contours. **Conclusions:** Placement of a custom-made hybrid TT, consisting of an appropriately coupled flange and ETT, may provide an exceptionally stable artificial airway for mechanically ventilated patients whose tracheal distortions preclude use of commercially available TTs with their typically shorter lengths. (OF-92-008)

Tracheotomy Fails To Improve Ventilation or Oxygenation in Traumatic Brain Injured Patients—Neil Finnen MD, Frederick W Clevenger MD, Stanley Whisenant MD, Turner M Osler MD. University of New Mexico, *Albuquerque, New Mexico.*

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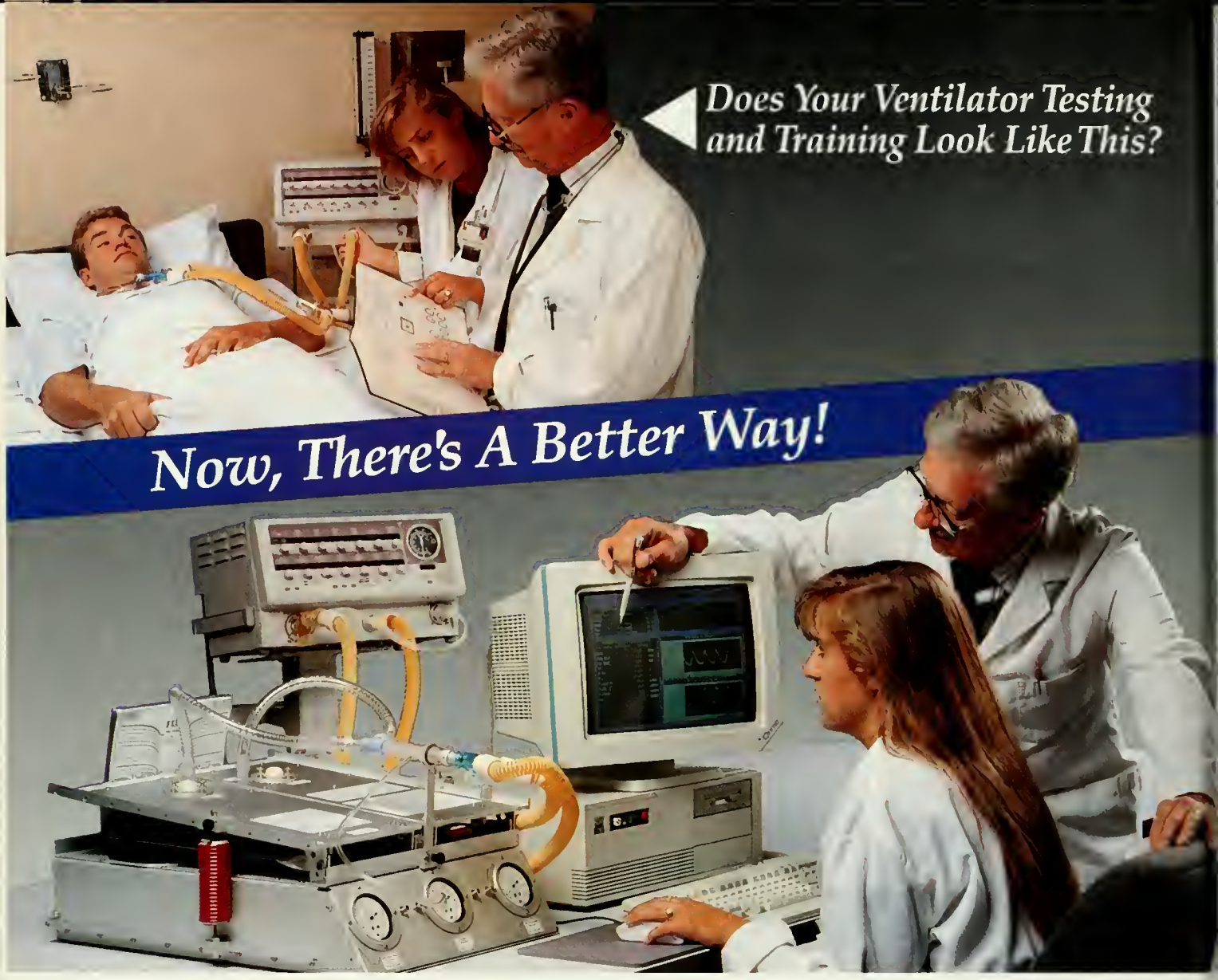

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lidity of this phenomenon, we reviewed charts of 120 patients receiving a tracheotomy at a Level-I Trauma Center. Thirty-four patients were chosen because they were a homogeneous group of traumatic brain injured (TBI) patients who required mechanical ventilation prior to tracheotomy and for at least 3 days following tracheotomy. These criteria were chosen so that effect of tracheotomy on oxygenation and ventilation could be determined. Outcome variables analyzed included ventilator rate, pH, P_{aCO_2}, and P_{aO_2}/F_{IO_2} ratio (oxygenation) on day prior to tracheotomy and for first 3 days post-tracheotomy. No statistically significant changes were seen between post-tracheotomy means and pre-tracheotomy means for arterial blood pH, P_{aCO_2}, and oxygenation (Dunnett's Test). Difference between pre-tracheotomy and 3-day post-tracheotomy [mean (SD)] were 7.47 (0.01) to 7.45 (0.01) for arterial blood pH ($p > 0.05$), 36 (1) torr to 38 (1) torr for P_{aCO_2} ($p > 0.07$), and 228 (10) torr to 230 (10) torr for oxygenation ($p > 0.88$). The power was 80% for differences of 0.02 for arterial blood pH, 2 torr for P_{aCO_2}, and 28 torr for oxygenation. There was no significant difference in ventilatory rate for day before and day after tracheotomy. Although the difference in ventilatory rate on day prior to tracheotomy (12.2 breaths/min) and on post-tracheotomy Day 2 (10.2 breaths/min) and Day 3 (9.7 breaths/min) was statistically significant, this decrease of < 3 breaths was probably not clinically important. Based on these data, we conclude that tracheotomy has no beneficial effect on arterial blood pH, P_{aCO_2}, or oxygenation over endotracheal intubation. The data fail to demonstrate any ventilatory or oxygenation mechanism that can explain why early tracheotomy shortens duration of mechanical ventilation. (OF-92-016)

New Criteria for Tracheotomy in Traumatic Brain Injury (TBI) Patients—Stanley Whisenant MD, Frederick W Clevenger MD, Neil Finnen MD, Turner M Osler MD. University of New Mexico, *Albuquerque, New Mexico.*

Indications for and timing of tracheotomy in TBI patients remains controversial. We reviewed charts of 77 TBI patients requiring tracheotomy for prolonged mechanical ventilation at a Level-I Trauma Center. Patients were divided into groups based on day of tracheotomy (Group 1 = 1-7; Group 2 = 8-14; Group 3 = 15-21; Group 4 = > 21). No differences were found in tracheotomy groups based on age, ISS (injury severity score), aGCS (abbreviated Glasgow Coma Scale), or indication for tracheotomy. Early tracheotomy (< 7 days) was significantly associated with decreased total mechanical ventilation days (TMVD) ($p < 0.05$). Late tracheotomy was associated with prolonged TMVD ($p < 0.01$) and intensive care unit stay ($p < 0.05$). Pneumonia was defined by criteria as established in previous publications. Less severe respiratory infections were associated with performance of an early tracheotomy ($p < 0.05$). Patients were also divided into groups based on age and severity of respiratory infection. Severe respiratory infections were associated with prolonged TMVD ($p < 0.05$), ICUD ($p < 0.01$), mechanical ventilation days after tracheotomy (MVDAT) ($p < 0.05$), and intensive care unit stay after tracheotomy (ICUDAT) ($p < 0.01$). Age > 40 was associated with a prolonged MVDAT, TMVD, ICUD, and ICUDAT (all $p < 0.01$). None of above calculations were affected by injury severity score (ISS) or severity of neurological injury (aGCS). Significantly different microorganisms were cultured during pre-tracheotomy and post-tracheotomy periods. Gram-positive bacteria *H influenza* were most common in pre-tracheotomy pneumonias, whereas gram-negative enteric organisms and *Pseudomonas* species were significantly more common in post-tracheotomy pneumonias ($p < 0.05$). There was no discernible increase in mortality associated with gram-negative or Pseudomonas pneumonia. Ventilated TBI patients with age > 40 and severe respiratory infections are at risk for prolonged mechanical ventilation and ICU stay. Early tracheotomy appears to be correlated with lower respiratory infection rate and may be appropriate in these patients to decrease the duration of mechanical ventilation. Early tracheotomy particularly appears to be useful in ventilator-dependent TBI patients who are > 40 years old or who develop pneumonia. Prospective studies are needed to validate this claim. (OF-92-018)

Effects of ETT Size, Vacuum Level, and Suction Catheter Size on Negative Pressures Generated during Endotracheal Suction—Arthur A Taft MHS RRT, Franklin H Dennison MEd RRT. Medical College of Georgia, *Augusta, Georgia.*

Endotracheal suction is a procedure commonly performed on intubated patients. Hazards are well documented, and many have been ascribed to negative pressures generated in lungs. Although numerous techniques have been developed to minimize these negative pressures, data have not been published regarding the actual pressures created during endotracheal tube (ETT) suction. Purpose of this study was to determine effects on intratest lung pressures (P_{TL}) as ETT size, vacuum level, and suction catheter size were varied. **Materials & Methods:** We modified a test lung (TTL, Michigan Instruments, Grand Rapids MI) by connecting ETTs of different sizes (6-, 7-, 8-, 9-mm ID) to inlet of one chamber. Intratest lung pressures, suction flows, and vacuum levels were measured with an RT-200 calibration analyzer (Timeter Corp, Lancaster PA), which was zeroed prior to each measurement. Vacuum levels (Ohmeda Critical Care) were varied from –80 to –160 torr (± 2 torr) and set with the suction tube occluded. Suction catheters (Superior Health Care Group Inc) of different sizes (10, 12, 14, 16 Fr) were then inserted through each ETT and suction port occluded. P_{TL} and suction flow were recorded once the readings stabilized. Statistical analysis was performed using 3-way ANOVA with $p < 0.05$ considered statistically significant. **Results:** There were statistically significant interactions between ETT size, vacuum level, and suction catheter size on P_{TL} ($p < 0.001$). P_{TL} increased (was more negative) as vacuum level and suction catheter size increased and decreased as ETT size increased. P_{TL} was < –9 cm H_2O at all combinations of ETT, suction catheter, and vacuum level except when the suction-catheter-to-ETT-area ratio (SC:ETT) was > 0.5. This corresponded to a suction catheter outside diameter (OD) that was approximately two thirds of the inside diameter of ETT. Statistically significant interactions were seen among ETT size,

vacuum level, and suction catheter size on suction flowrates ($p < 0.005$). Mean (SD) values for suction flow ranged from 8.0 (0.06) L/min with 10 Fr at –80 torr to 16.0 (0.06) L/min with 16 Fr at –160 torr and increased as vacuum level, suction catheter size, or ETT size increased. ETT size had little effect on suction flowrates if SC:ETT < 0.44. **Conclusions**: Current guidelines for choosing suction catheters based on their OD being ≤ to one half the ID of the ETT may be too conservative. We found pressures to be quite low when suction catheters with OD as large as two thirds of the ETT ID were used. Also, when vacuum levels are set with suction tubing occluded, vacuum levels of –160 torr do not appear to generate large negative intratest lung pressures when SC:ETT is < 0.5. (OF-92-027)

Evaluation of a Lighted Stylet To Assess Endotracheal Tube Position—Dean Hess MEd RRT, Khaleel Shaikh MD. York Hospital and Community Medical Center, *York and Scranton, Pennsylvania.*

Introduction: Placement or movement of an endotracheal tube (ETT) into a main-stem bronchus is a common problem. A recent cadaver study suggested that a lighted stylet may be useful to assess ETT position (Crit Care Med 1990;18:97). The purpose of our study was to evaluate the use of a lighted stylet to assess endotracheal tube position in adult critically ill patients. **Methods**: The study population consisted of 100 patients (61 men, median age 42.5 y), all of whom were intubated for reasons unrelated to this study. The median ETT size was 8.0-mm ID (81 oral and 19 nasal). Tubes were trimmed so that only 1.5 cm extended from nose or mouth. Patients were preoxygenated with 100% O_2, and pulse oximetry and heart rate were monitored. Stylet was lubricated, passed through a bronchoscopy port without interruption of ventilation, and advanced until its tip approximated distal endotracheal tube. Transillumination of sternal notch was assessed, and its presence was interpreted as a correctly positioned ETT. Position of ETT tip was determined by chest radiograph obtained near time of procedure. For the first 45 patients, a Flexi-Lum Surgical Light Stylet (Concept Inc, Clearwater FL) was used, and a Tube-Stat Nasotracheal Intubation Stylet (Concept Inc, Clearwater FL) was used for remaining 55 patients. **Results:** Stylet could not be passed through the ETT in 7 cases, and transillumination did not occur in 4 cases. Because all of tubes were correctly positioned [mean (SD) distal tip = 4.8 (1.1) cm above carina, as determined by chest radiography], the sensitivity of stylet for detection of proper ETT position was 89%. The performance of the Tube-Stat (96.4% sensitivity) was superior to that of Flexi-Lum (80% sensitivity) ($p = 0.009$). There was no difference between nasal and oral intubations ($p = 0.12$), or between sizes of ETTs (< 8.0-mm ID and > 8.0-mm ID) ($p = 0.16$). A darkened room and pressure on anterior neck facilitated transillumination. Because 96 patients were Caucasian, effect of skin pigmentation could not be assessed. **Conclusions:** We found a high sensitivity (89%) of lighted stylet to detect correctly placed ETTs, which suggests that this procedure may be useful in lieu of chest radiography in some adult patients. However, this study design did not allow specificity of technique to be evaluated (ie, the ability of the lighted stylet to detect incorrectly placed ETTs). Tube-Stat was superior to Flexi-Lum. Further work is needed to assess usefulness of lighted stylet to reposition ETTs in presence of a main-stem intubation. Further work is also needed to assess this device in individuals with deeply pigmented skin. (OF-92-045)

Evaluation of the Effects of Fatigue, Impedance, and Use of Two Hands on the Volumes Delivered during Bag-Valve Ventilation—Dean Hess MEd RRT, Mark Simmons MSEd RPFT RRT, Debra Lightner, Scott Blaukovitch. York Hospital and York College, *York, Pennsylvania.*

Introduction: We conducted this study to evaluate effects of fatigue, impedance (resistance and compliance), and use of 2 hands on volumes delivered during bag-valve ventilation (BVV). **Methods:** BVV was delivered to a Michigan Instruments TTL. An adult Laerdal resuscitator with gas collection head was used. A Bear VM-90 was used to measure exhaled volumes, and its accuracy was confirmed using a calibration syringe. All participants (n = 14) were BCLS certified and were familiar with BVV. Each person ventilated the TTL for 30 min with same technique used during patient BVV. Each tidal volume (V_T) was recorded for Minutes 2, 15, and 30. Grip strength was measured using a mechanical digital grip strength tester for both dependent and independent hands before and after each 30-min trial. Each subject participated 4 times: using 1 hand and 2 hands with low impedance (compliance of 50 mL/cm H_2O, resistance of 5 cm H_2O/L/s) and high impedance (compliance of 20 mL/cm H_2O, resistance of 20 cm H_2O/L/s). Order of testing was randomly determined and a minimum 30-min recovery period was allowed between test periods. Differences between V_T at 3 measurement points and differences in grip strength were evaluated by ANOVA. **Results:** The V_T delivered are shown in table [L, mean (SD)].

Test Condition	Minute 2	Minute 15	Minute 30
One hand			
Low impedance	0.73 (0.12)	0.72 (0.15)	0.73 (0.14)
High impedance	0.59 (0.08)	0.59 (0.07)	0.58 (0.06)
Two hands			
Low impedance	0.99 (0.20)	1.00 (0.19)	0.96 (0.17)
High impedance	0.84 (0.18)	0.90 (0.19)	0.86 (0.20)

There was no significant difference in V_T for three measurement periods ($p = 0.16$). However, there was a significant difference in V_T for impedance levels ($p = 0.002$) and for 1 hand versus 2 hands ($p < 0.001$). There was a small but significant decrease in grip strength for dependent hand [35.9 (7.2) kg before, 34.8 (7.9) kg after, $p = 0.02$], but no change in grip strength for independent hand [32.5 (7.3) kg before, 32.4 (7.7) kg after, $p = 0.73$]. **Conclusions**: There was little change in V_T during BVV over the 30-min evaluation period used in this study. Effect of lung impedance and using 2 hands for BVV

was greater than effect of fatigue. Further work is needed to assess effect of fatigue using different bag-valve resuscitator brands. (OF-92-048)

Resistance to Flow through the Valves of Mouth-to-Mask Resuscitation Devices—Dean Hess MEd RRT, Faith Slikkers, Rebecca Dickerson, Mark Simmons MSEd RPFT RRT. York Hospital and York College, *York, Pennsylvania.*

Introduction: The American Heart Association recommends that mouth-to-mask ventilation be taught to health care providers, and many hospitals now provide these devices at bedside of all patients. These devices, available from several manufacturers, differ in their designs. We performed this study to determine inspiratory and expiratory flow resistance of valves of commercially available mouth-to-mask resuscitation devices. The International Standards Organization (ISO) states that back pressure through resuscitator valves should be < 5 cm H_2O at a flow of 50 L/min. **Methods:** We evaluated valves of 8 mouth-to-mask ventilation devices (Intertech, Laerdal, LDS, Res-Q, Respironics, Rondex, Vital Signs, White). Devices were supplied by manufacturers and included valve and any filter or extension tube supplied with valve. Expiratory resistance was evaluated by directing air through valve in direction of flow when patient exhales. Inspiratory resistance was evaluated by directing air through valve in direction of flow when a tidal volume is delivered to patient. Flow was controlled by a Timeter 0-75 flowmeter, and measured using a calibrated Timeter RT-200. Flows of 10, 20, 30, 40, 50, 60, 70, 80, and 90 L/min were used. Back pressure due to resistance of valves was measured using a calibrated Timeter RT-200. Resistance was calculated by dividing back pressure by flow. Five measurements were made at each flow setting for each valve. Statistical analysis consisted of analysis of variance and calculation of mean (SD). **Results:** There were differences in back pressure and resistance between flows evaluated ($p < 0.001$ for both inspiratory and expiratory flows) and between commercially available devices ($p < 0.001$ for both inspiratory and expiratory flows). There were also significant interaction effects for valve back pressure and flow and resistance and flow ($p < 0.001$ in each case). At a flow of 50 L/min (the ISO standard), inspiratory back pressures (cm H_2O) produced by the devices were 5.2 (0.06), 4.6 (0.09), 4.7 (0.03), 3.1 (0.04), 33 (0.04), 1.1 (0.02), 4.0 (0.06), and 4.3 (0.10) for Intertech, Laerdal, LDS, Res-Q, Respironics, Rondex, Vital Signs, and White, respectively. At a flow of 50 L/min, expiratory back pressure (cm H_2O) was 4.8 (0.30), 9.1 (0.10), 33 (0.02), 3.7 (0.35), 0.5 (0.01), 1.4 (0.01), 3.6 (0.05), and 13.7 (0.48) for Intertech, Laerdal, LDS, Res-Q, Respironics, Rondex, Vital Signs, and White, respectively. **Conclusions:** To our knowledge, resistance to flow through these devices has not been previously reported. In some cases, resistance through these devices might be considered excessive. Excessive inspiratory resistance could result in fatigue for rescuer, and excessive expiratory resistance could result in auto-PEEP for patient. Because this was a bench study, further work is needed to determine clinical importance of these findings. (OF-92-049)

The Use of a Relative Efficiency Index (EI) for Comparing the Fraction of Delivered Oxygen (F_{DO_2}) and Tidal Volume (V_T) Delivered by 7 Disposable Adult Manual Resuscitators (DAMRs)—Russell T Reid RCP. UC-Davis Medical Center, *Sacramento, California.*

When DAMR performance characteristics are compared, delivered V_T and F_{DO_2} are 2 important variables. Determining which DAMR is most efficient may be difficult when DAMR with low F_{DO_2} and large V_T is compared to DAMR with greater F_{DO_2} and smaller V_T. I developed EI to assist in evaluation. **Methods:** Each DAMR was connected to a TTL lung model (Michigan Instruments Inc) manually ventilated at 12, 20, and 30 cycles/min at compliance settings of 0.02, 0.04, and 0.10 L/cm H_2O. Airway resistance remained constant at 20 cm H_2O/L/s. 5 repeat measures of 1-min duration were performed for each DAMR at each randomly selected combination of cycle rate and TTL-compliance settings. Each of 7 DAMRs were tested on different days to minimize effect of hand fatigue, using 2 hands (#8 glove size) with unrestricted refill. Airway pressure data [mean (SD)] were collected by an electronic pressure transducer (Pneumogard 1230A) and held constant at 50.9 (0.5) cm H_2O. Volumes were measured by placing Wright respirometer at proximal airway connection, and F_{DO_2} was analyzed using polarographic oxygen analyzer. Each DAMR had oxygen flowrate of 15 L/min and I:E of 1:3.7 (1.0). All equipment was calibrated prior to each set of trials according to manufacturers' recommendations. EI is calculated: (1) Mean V_T (liters)/Compliance Setting (liters) = "Ideal Pressure" for volume delivered; (2) "Ideal Pressure"/(Actual Peak Pressure – PEEP) = "Delivered Volume Efficiency" expressed as %; (3) "Delivered Volume Efficiency" × Measured F_{DO_2} = EI. **Results:**

DAMR	C_L (cm H_2O)	Efficiency Index at 12/20/30 Cycles/Min
Inspiron	0.02	0.50 / 0.31 / 0.30
Inspiron	0.04	0.29 / 0.25 / 0.18
Inspiron	0.10	0.14 / 0.11 / 0.08
Ambu	0.02	0.58 / 0.37 / 0.32
Ambu	0.04	0.32 / 0.22 / 0.20
Ambu	0.10	0.14 / 0.11 / 0.09
Vital Signs	0.02	0.50 / 0.42 / 0.40
Vital Signs	0.04	0.31 / 0.24 / 0.22
Vital Signs	0.10	0.14 / 0.11 / 0.09
LDS*†	0.02	0.43 / 0.42 / 0.32
LDS†	0.04	0.32 / 0.25 / 0.19
LDS†	0.10	0.14 / 0.11 / 0.10
Respironics	0.02	0.51 / 0.42 / 0.33
Respironics	0.04	0.36 / 0.20 / 0.19
Respironics	0.10	0.15 / 0.11 / 0.08
P-B‡	0.02	0.58 / 0.47 / 0.36
P-B	0.04	0.31 / 0.26 / 0.20
P-B‡	0.10	0.15 / 0.12 / 0.09
LSP	0.02	0.58 / 0.47 / 0.33
LSP‡	0.04	0.32 / 0.26 / 0.24
LSP‡	0.10	0.14 / 0.13 / 0.09

* LDS = Life Design Systems; P-B = Puritan-Bennett; LSP = Life Support Products.

† LDS had measurable auto-PEEP. Mean value (SD) cm H_2O at following cycles/min and all compliance levels—12 cycles/min 5.1 (3.7), 20 cycles/min 8.9 (0.5), and 30 cycles/min 7.8 (0.9).

‡ Indicates most efficient DAMR at 10, 20, and 30 cycles/min and respective compliance setting.

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Conclusion: This EI evaluates relative efficiency using 2 important measured variables. The 'perfect' DAMR would have a value of 1.00 indicating a delivered F_{DO_2} of 100% and no loss of driving pressure to resistance. Differences exist in relative efficiency of the 7 DAMRs. I speculate that body geometry and volume, valve resistance (reservoir inlet, inspiratory, expiratory), reservoir geometry and volume, and body material affect DAMR efficiency. (OF-92-063)

The Effects of Mask Design on Delivered Volume during Mouth-to-Mask and Ventilator-to-Mask Ventilation of a Patient Model—Richard D Branson RRT, Robert S Campbell RRT, Kenneth Davis Jr MD, Daniel J Johnson MD. University of Cincinnati Medical Center, *Cincinnati, Ohio.*

We studied effects of mask design on delivered V_T during ventilator-to-mask and mouth-to-mask ventilation. We used a Resusci-Anne connected to test lung (C_L of 0.1 and 0.02 L/cm H_2O) by a tracheal model. Esophagus was simulated by 20-cm Penrose drain and 20-cm-H_2O PEEP valve. 15 volunteers trained in BLS ventilated model using ventilator-to-mask and mouth-to-mask techniques with 5 masks: Vital Signs 1 (VS1), Vital Signs 2 (VS2), Respironics, King Systems, & Intertech. Masks were used in random order. Hand size and grip strength of each volunteer were recorded. During 2-3 min periods, delivered V_T, PIP, and f were continuously recorded using a Bicore CP-100 monitor. Gastric volumes (GV) were collected leaving PEEP valve and recorded. Ventilator was set to deliver V_T of 1.0 L at t_I of 1.5 s. During mouth-to-mask ventilation, volunteers were instructed to deliver V_T, rates, and t_I according to AHA guidelines. Adequacy of V_T was assessed by expansion of test lung. Volunteers were blinded to actual volume and pressure measurements. Mean (SD) V_Ts, GV, and PIP at lung C_L of 0.02 L/cm H_2O for both techniques are shown.

Ventilator to Mask

	VS1	VS2	Respironics	King	Intertech
V_T (L)	0.70 (0.04)	0.68 (0.05)	0.5 (0.09)*	0.70 (0.04)	0.56 (0.09)*
GV (L)	0.13 (0.02)	0.13 (0.02)	0.05 (0.01)	0.13 (0.02)	0.07 (0.02)
PIP (cm H_2O)	24 (2)	22 (3)	17 (3)	22 (3)	16 (5)

*$p < 0.01$ compared to VS1, VS2, and King masks.

Mouth to Mask

	VS1	VS2	Respironics	King	Intertech
V_T (L)	0.79 (0.09)	0.81 (0.13)	0.81 (0.12)	0.78 (0.10)	0.67 (0.13)*
GV (L)	0.38 (0.14)	0.34 (0.05)	0.30 (0.17)	0.38 (0.07)	0.30 (0.15)
PIP (cm H_2O)	25 (6)	25 (4)	23 (6)	25 5)	23 (4)

*$p < 0.01$ compared to other masks.

During ventilator-to-mask ventilation, V_Ts delivered via VS1, VS2, and King masks were equivalent, but V_Ts using Intertech and Respironics masks averaged > 0.1 L less. Analysis of V_Ts according to sex of operator demonstrated no differences except with use of Respironics mask (V_T delivered by women was < by men, 0.45 vs 0.70 L). During mouth-to-mask ventilation, all masks performed equally except for Intertech mask (volume 0.12 L < other masks). Analysis of results by sex revealed a consistently larger V_T delivered by men (0.8 L vs 0.51 L). Hand size was similar between sexes, but grip strength was 47 kg for men vs 31 kg for women. Results suggest that mask design plays an important role in efficacy of mouth-to-mask and ventilator-to-mask ventilation. Grip strength also appears to be important in delivery of adequate V_T. Comparison of mouth-to-mask and ventilator-to-mask techniques demonstrates a larger V_T with mouth-to-mask but also greater gastric insufflation. During mouth-to-mask ventilation, men delivered greater volumes than women. (OF-92-080)

Tracheostomy Discontinuance and Tracheostomy Tube Selection: Airway Resistance during Tracheostomy Tube Occlusion—Barry Beard BA RRT, Penrose-St Francis Health Care; Frank J Monaco BA RRT, Memorial Hospital—*Colorado Springs, Colorado.*

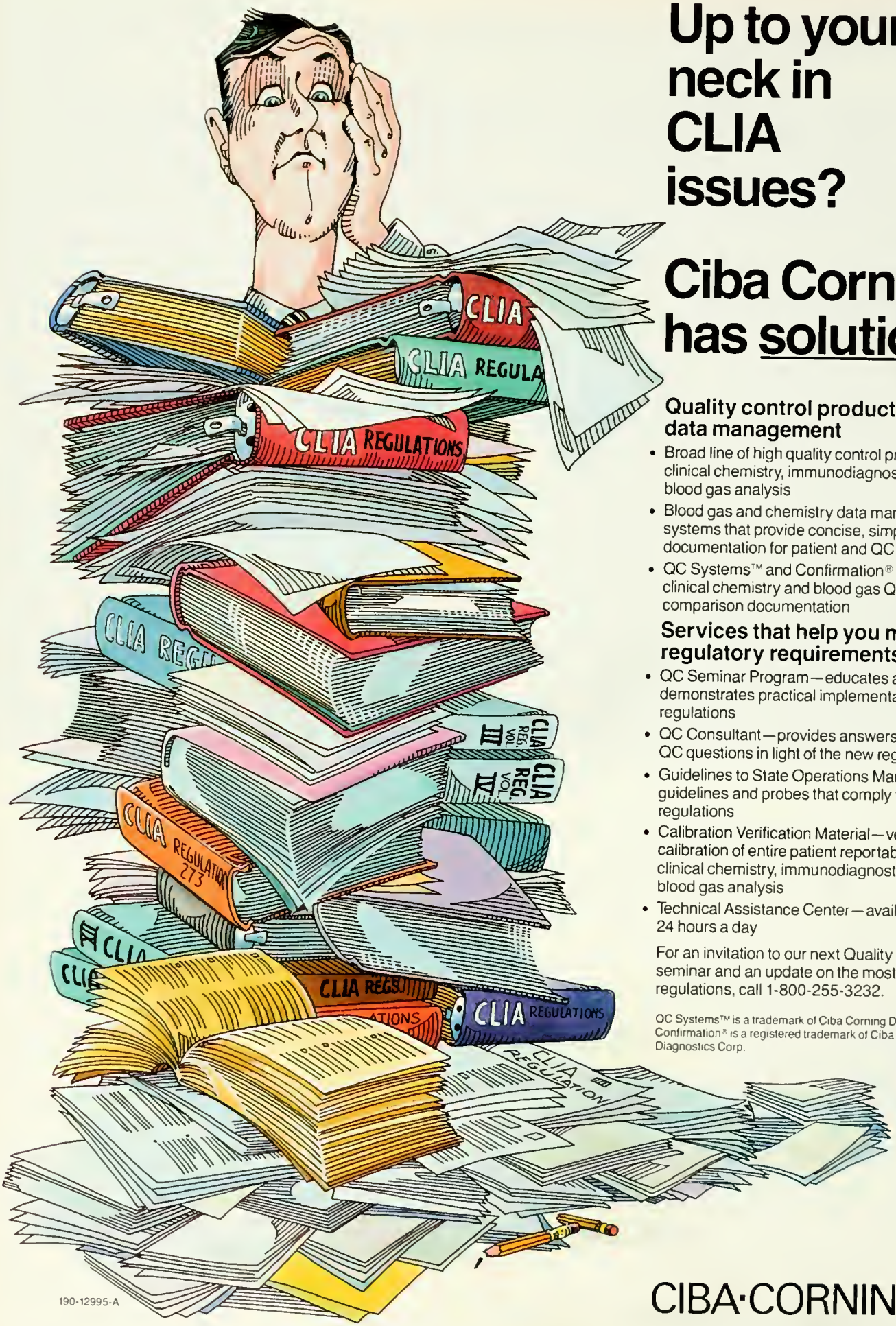
During tracheostomy discontinuance trials when tracheostomy tubes are occluded, it may be expected that transition from tracheostomy to laryngeal ventilation will be accompanied by an increase in airway resistance (R_{aw}). This study was undertaken to determine extent to which different types of tracheostomy tubes contribute to increases in R_{aw}. R_{aw} was determined using model tracheas with various types of occluded tracheostomy tubes in place and varying gas flowrates. Gas flowrate and intratracheal pressures superior and inferior to tracheostomy tube were measured with a Timeter RT-200 calibration analyzer. R_{aw} (kPa/L/s) for the various tube configurations were

	Inspiratory Gas Flow (L/s)				
Tube Type*	0.33	0.67	1 00	1.33	1.50
Cuffed-fenestrated, cuff-inflated	0.16†	0.30	0.44	0.59	0.64
Cuffed-fenestrated, cuff-deflated	0.08	0.13	0.19	0.24	0.27
Non-cuffed fenestrated	0.03	0.05	0.06	0.08	0.08
Jackson	0.04	0.07	0.09	0.11	0.13

*All tubes size 8.
†Values are R_{aw} in kPa/L/s.

Results suggest that type of tracheostomy tube applied during tracheostomy discontinuance trials affects amount of ventilatory work required of patient. It is recommended that non-cuffed tubes be applied where possible. (OF-92-084)

Work of Breathing Imposed by Tracheostomy and Stomal One-Way Valves—Robert M Kacmarek PhD RRT, Sylvester Barker LPN. Massachusetts General Hospital, *Boston, Massachusetts.*



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In transition from standard tracheostomy tubes to decannulation in patients with long-term artificial airways, various types of tracheostomy tube one-way speaking valves (T) or stomal one-way valves (S) are used. We questioned whether work of breathing imposed (WOB_I) by these devices differed and whether WOB_I was excessive. **Methods:** Using a Michigan Instruments TTL, and a Puritan-Bennett 7200 ventilator as a power source, we established a 'spontaneously' breathing (SP) lung model. We determined WOB_I using a Bicore CP-100 monitor during simulated SP through 3 tracheostomy tube valves (T): Passy Muir (P), Montgomery (M), and Hood (H), and 3 stomal valves (S): Kistner (K), Olympic (O), and Hood (H) at the following tidal volumes (V_T) and peak inspiratory flows (decelerating waveform) 0.3 L, 0.66 L/s; 0.5 L, 1.0 L/s; 0.7 L, 1.16 L/s. **Results:** The following are the WOB_I (SD) joules/L of 5 breaths at various V_Ts (L):

V_T	K-S	H-S	O-S	P-T	M-T	H-T
0.3	0.9516	1.4236	0.2516	0.3388	0.1996	1.5548
	(0.0659)*	(0.00)*	(0.0004)*	(0.0002)*	(0.0005)	(0.0032)*
0.5	1.4368	____†	0.5440	0.55848	0.3148	____†
	(0.0645)*		(0.0014)*	(0.0003)*	(0.0002)	
0.7	1.6880	____†	0.7216	0.7064	0.4428	____†
	(0.0792)*		(0.0016)*	(0.0006)*	(0.0002)	

*$p < 0.05$ vs M-T one-way ANOVA
†Unable to establish these ventilatory patterns with either Hood valve.

Conclusion: There are significant differences in WOB_I among both T and S valves. The Montgomery valve outperformed all others, whereas the Hood valves imposed the greatest WOB. (OF-92-103)

Ventilatory Volumes Achieved with a Bag-Valve Device vs a Transport Ventilator—Thomas A Barnes EdD RRT. Northeastern University, *Boston, Massachusetts.*

Ventilatory volumes delivered to a lung analog were compared using a bag-valve device (BVD) and a transport ventilator (IC-2A, Bio-Med Devices Inc). Skill with each device was checked against American Heart Association (AHA) recommendation of 12 ventilations/min, each with a $V_T \geq 800$ mL. **Method:** I assessed ability of 10 respiratory therapy students to ventilate Bio-Tek VT-1 Ventilator Tester with BVD and manually triggered IC-2A. Students had previously been trained and evaluated in use of BVD but had no experience with IC-2A. Before testing, each student was given < 5 min of instruction on IC-2A. All 10 students ventilated the VT-1 for 10 min using both BVD and IC-2A randomly selected. The BVD was squeezed using only 1-hand and IC-2A was manually triggered. Number of 800-mL V_Ts in first 2 min and over 10 min was recorded. VT-1 was configured with compliance of 0.020 L/cm H_2O [0.20 L/kPa] and resistance of 20 cm H_2O/L/s [2 kPa/L/s]. **Results:**

	BVD	IC-2A
2-min assessment*	5.5 (5.3)	10.8 (3.8)
10-min assessment*	8.1 (4.8)	10.8 (3.8)

*All values are mean (SD) successful 800-mL V_T/min.

Significant difference existed between 2-min assessments when BVD was compared to IC-2A (ANOVA, $p < 0.02$). No significant differences existed between 10-min assessments of BVD and IC-2A (ANOVA, $p = 0.18$). No significant differences in improvement existed during 10-min settling-in period for both BVD and IC-2A (ANOVA, $p = 0.26$, 1.00, respectively). IC-2A can be used to deliver 800-mL V_T at a success rate very close to that achieved with BVD. In first 2-min, use of IC-2A appears to be more reliable than BVD in delivering 800-mL V_T. More study is needed in use of manually triggered transport ventilators during resuscitation. (OF-92-121)

Use of the Bubble Inclinometer (BI) To Predict Excessive Tracheostomy (T-) Tube Minimal Occlusive Cuff Pressure (MOP)—Kenneth E Shepherd MD, Ray Ritz RRT. Massachusetts General Hospital, *Boston, Massachusetts.*

Abnormal alignment of a T-tube within a patient's airway necessitates overinflation of the cuff to obtain an adequate seal. This causes the normally low-pressure cuff to lose its mechanical advantage and transmit excessive lateral tracheal wall pressure with resultant ischemic injury. T-tubes that closely match the structure of the anatomic airway should allow proper alignment and reduce MOP. Currently no a priori objective measurement exists to aid in selecting tubes (design characteristics vary among manufacturers) that closely conform to the anatomic airway. We hypothesized that an airway characteristic, laryngotracheal (LT) tilt, is the main variable leading to excessive MOP. To test this, we correlated degrees of LT tilt with MOP. **Method**: All patients (n = 20) included in this study (approved by Human Studies) had initial placement of Portex T-tubes (the convention at our hospital), normal lung compliance, and no known LT abnormality. LT tilt was determined noninvasively by placing a slightly modified BI (Sears Roebuck and Co) on the thyroid cartilage; the degree of tilt from the horizontal was recorded (Roberts et al, Anesthesiology 1990;73:A1035). The respiratory care chart was then examined for MOP; > 25 torr was considered excessive. **Results**: LT tilt varied between 0 and 30°, MOP between 20 and 45 torr. Poor correlation (r = 0.22) was found between LT tilt and MOP. **Conclusion**: Other factors related to malalignment (eg, tube and cuff contour) and/or unrelated factors (eg, unrecognized LT variations not predictable from anterior measurements and/or improper tube size) appear to contribute importantly to MOP. Because these confounding factors are not accounted for by the BI measurements, LT tilt alone is not helpful in predicting excessive MOP. (OF-92-183)

Facets of Mechanical Ventilation

A New Mathematical Method for Predicting the T_E Necessary To Achieve a Desired $PEEP_I$—Michael R Jones RRT, John Rimes RRT, Paul B Blanch BS RRT. Shands Hospital at the University of Florida, *Gainesville, Florida.*

Introduction: Intrinsic PEEP ($PEEP_I$) frequently occurs during mechanical ventilation with short expiratory times (T_E). A number of authors have begun to describe $PEEP_I$ as a therapeutic variable to be manipulated much like extrinsic PEEP ($PEEP_E$). $PEEP_I$ is defined as difference between alveolar end-expiratory pressure and $PEEP_E$. Our efforts to employ $PEEP_I$ clinically and measure its efficacy have been hindered by the complications associated with multiple ventilator adjustments required to effect a desired change in $PEEP_I$. Using the exponential relationship between pressure and time during lung deflation (Eq. 1), we have developed the following single, composite function, logarithmic equation that predicts the T_E necessary to achieve a desired $PEEP_I$ (Eq. 2).

$$PEEP_I = (P_{plateau} - PEEP_E)(e^{-TE/RC}) \quad [1]$$

$$T_E = ln \left[\frac{(P_{plateau} - PEEP_E)}{PEEP_{I\,(desired)}} \right] \left[\frac{T_{Einitial}}{ln \left(\frac{P_{plateau} - PEEP_E}{PEEPI\,(initial)} \right)} \right] \quad [2]$$

Study Question: Will Eq. 2 adequately predict T_E necessary to achieve a desired $PEEP_I$ once an initial $PEEP_I$ and T_E are measured? **Materials & Methods:** We used a test lung (Michigan Instruments TTL) with resistance of 25 cm H_2O/L/s and compliance of 0.05 L/cm H_2O, a mechanical ventilator (Hamilton Veolar), and a recording pressure monitor (Novametrix Pneumogard) to measure T_E and alveolar and airway pressures. $PEEP_E$ was set to 0. Using various measured T_E, we measured an initial $PEEP_I$, calculated necessary T_E to achieve a new target $PEEP_I$, and set T_E to that setting. New $PEEP_I$ was measured using exhalation-valve-occlusion technique and verified by direct measurement of alveolar pressure using alveolar port on the TTL. **Results:**

Target $PEEP_I$	13	17	12	15	Linear Regression:
Measured $PEEP_I$	14	17	11	14	$r = 0.92$, $r^2 = 0.85$

Mathematical integrity of Eq. 2 was checked by manually calculating numerous deflation curves using Eq. 1 and checking those values against Eq. 2. There was perfect identity. **Conclusion:** This technique provides very good prediction of required T_E to achieve a new $PEEP_I$ using a single-compartment lung model. (OF-92-058)

Routine Nasal Mask Pressure Support Ventilation in Recently Extubated Postoperative Patients—Sharon Day RRT, Mike Griffis RRT, Neil R MacIntyre MD, Chris Hidinger RRT, Pat Robbins RRT, Sherry Whitfield. Duke University Medical Center, *Durham, North Carolina.*

Introduction: An aggressive extubation strategy for postoperative patients is important to reduce complications; however, some patients will not tolerate early extubation. Reintubation is often a consequence of increased ventilatory work load due to atelectasis, muscle weakness, and/or airway dysfunction from residual anesthesia and/or analgesia. Noninvasive pressure support through a nasal mask (BiPAP, Respironics) may provide short-term adequate ventilatory support for such patients in immediate postextubation phase. To test this, we studied postoperative cardiac surgery patients in our thoracic surgery unit from February 1991 to December 1991. **Methods**: All cardiac surgery patients who consented preoperatively for randomization were included in study. Prior to extubation, we measured ventilatory mechanics, ventilator settings, F_{IO_2}, and arterial blood gases. Immediately upon extubation, patients were randomized to receive either 10-cm inspiratory pressure by BiPAP or standard O_2 therapy. We recorded immediately after extubation, at the 24-hour mark, and, finally, after 48 hours of initial extubation: medications, cardiac rhythm, chest x-ray patterns, vital signs, arterial blood gas values, and whether the patient required reintubation, respiratory care services, or experienced any clinically significant events. Paired comparisons were made by *t* test ($p < 0.05$ considered significant). **Results:** 467 patients were entered into study. 199 patients received BiPAP and 268 were placed on conventional O_2 therapy (venturi mask or cannula). Reintubation rate was BiPAP 10 of 199, or 5%, and conventional 9 of 268, or 3.4% (p = NS). Of 19 total reintubations, 9 were performed on patients who needed a surgical procedure (5 BiPAP and 4 conventional). Among other variables, there were no significant differences except that BiPAP group had significantly faster development of normal chest x-rays after 24 hours (45% vs 33%, $p < 0.05$). We identified a subgroup of 51 patients who were at high risk for reintubation based on respiratory rate, dynamic and static compliance, need for bronchodilator therapy, need for suctioning, and O_2 requirements. 4 of 9 nonsurgery-related reintubations occurred in this group, with 1 in the BiPAP group and 3 in conventional therapy group. **Conclusion:** We conclude that routine application of BiPAP in all postoperative patients does not appear to be justified. However, because chest x-rays resolved significantly faster in the BiPAP group and because reintubations tended to be lower in high risk group receiving BiPAP, selective application of BiPAP in patients at high risk of reintubation from respiratory causes may be useful. (OF-92-087)

Prolonged-Inspiratory-Time Ventilation as an Alternative to Positive End-Expiratory Pressure To Increase Mean Alveolar Pressure and $P_{a(O)_2}$—Bruce Armstrong PA-C MS, Neil R MacIntyre MD. Duke University Medical Center, *Durham, North Carolina.*

Introduction: Positive end-expiratory pressure (PEEP) is commonly used to maintain alveolar stability in patients with severe lung injury. A necessary consequence of PEEP, however, is an elevation of maximal alveolar distending pressure—a known risk factor for both alveolar injury and rupture. Support strategies to stabilize alveoli with less maximal distending pressures would thus seem desirable. One such strategy is use of longer inspiratory times as an alternative to PEEP. This ap-

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proach maintains an elevated mean alveolar pressure (and thus alveolar stability) without a necessary increase in baseline or maximal pressures. We report here our experience with this approach from September 1990 through July 1991. **Method:** Patients were selected for prolonged-inspiratory-time ventilation (PITV) if they had ARDS and if peak airway pressures required for adequate ventilatory and oxygen support on conventional volume-cycled ventilation (VCV) exceeded 50 cm H_2O. The pressure control mode was used with frequency, inflation pressures, and inspiratory time (t_I) initially set to mimic pattern of VCV. PEEP was not changed. Mean airway pressure was then progressively increased using longer t_I. The t_I, however, was held below that which would produce air trapping (auto-PEEP) to maintain constant maximal alveolar pressure. Data collection during baseline VCV period and during PITV over a subsequent 12-h period included ventilator mechanics, arterial blood gases, and hemodynamics. Analysis consisted of paired *t* test with $p < 0.05$ considered significant. **Results:** 14 patients were given PITV. Data are mean (SD).

	Peak P_{aw} (cm H_2O)	$\bar{P}_{aw}$	V_T (mL)	f (b/min)	P_aCO_2 (torr)	P_aO_2/F_IO_2	OI*	Mean BP (torr)	Heart Rate
VCV	53 (3)†	20 (1)†	879 (38)	18 (1)	39 (4)	93 (14)†	4.6 (2.1)	74 (4)	115 (7)
PITV	40 (2)†	30 (2)†	885 (69)	16 (1)	35 (3)	128 (15)†	4.5 (1.9)	75 (3)	107 (7)

* OI = oxygenation index = $P_aO_2/(F_IO_2)(\bar{P}_{aw})$
† $p < 0.05$

Conclusion: We conclude that PITV via pressure-controlled ventilation is alternative to PEEP to raise mean alveolar pressure without necessary increase in maximal alveolar pressure. This increase in mean alveolar pressure is associated with an increase in P_aO_2 that is in accordance with a constant oxygenation index $P_aO_2/(F_IO_2)(\bar{P}_{aw})$. (OF-92-088)

The Effect of Increasing Mechanical Ventilation during Chest Physical Therapy on Oxygen Delivery and Oxygen Consumption—Marcia S Kemper BA CRTT, James Harding, Charles Weissman MD. Columbia University, *New York, New York.*

Chest physical therapy (CPT) increases $\dot{V}_{O_2}$ by approximately 40% & $\dot{V}_E$ by 35% during IMV. Possible causes for the $\dot{V}_{O_2}$ increase include movement of limbs, increased catecholamines due to pain, or the increased work of breathing from the increased $\dot{V}_E$. We sought to determine if $\dot{V}_{O_2}$ increase could be attenuated by increasing mandatory respiratory rate of ventilator during CPT. 13 studies were performed on 15 mechanically ventilated postoperative patients (pts). A standardized CPT regimen (side/back/side/back with percussion for 2 min in each side position) was performed twice, once without and once with mandatory breath rate increased by 35%, in random order. Resting metabolic, blood gas, and ventilatory values were recorded before and after CPT. A SensorMedics Deltatrac determined $\dot{V}_{O_2}$ and $\dot{V}_{CO_2}$. Alveolar ventilation (V_A) was calculated as $[V_A = \dot{V}_{CO_2}(0.836)/P_aCO_2]$.

		Rest	CPT	Rest
$\dot{V}_{O_2}$ (mL/min)	Baseline	211 (33)*†	317 (81)	205 (31)
	IRR	207 (27)†	295 (103)	207 (37)
P_aCO_2 (torr)	Baseline	35.9 (4)†	39.3 (4)	37.1 (4)
	IRR	36.7 (3)	37.5 (5)‡	36.4 (4)
pH	Baseline	7.44 (0.1)†	7.40 (0.1)	7.43 (1)
	IRR	7.43 (1)	7.42 (0.1)‡	7.44 (0.1)
$\dot{V}_E$ (L/min)	Baseline	8.3 (2)†	10.3 (2)	8.1 (2)
	IRR	8.2 (2)†	11.9 (3)‡	7.9 (2)
RR (breaths/min)	Baseline	10.8 (3)†	19.8 (6)	11.9 (3)
	IRR	11.0 (3)†	21.2 (8)	10.6 (3)
V_A (L/min)	Baseline	4.4 (1.0)†	5.1 (1.2)	4.2 (0.95)
	IRR	4.3 (0.85)†	5.7 (1.6)	4.1 (0.85)

*Values are mean (SD). IRR = increased respiratory rate.
†Significantly different from CPT values ($p < 0.01$).
‡ Significantly different from baseline values ($p = 0.01$).

Increasing mandatory rate prevented rise in P_aCO_2 during CPT. Increase in $\dot{V}_{O_2}$ was unaffected by increase in IMV rate as pts continued to initiate respiration. Because total respiratory rate was not significantly changed by this maneuver, contribution of increased $\dot{V}_E$ to increased $\dot{V}_{O_2}$ remains unclear. (OF-92-099)

The Effect of Applied ($PEEP_A$) vs Auto-PEEP ($PEEP_I$) on Local Distribution of Volume and Pressure in a Four-Chamber Lung Model—Max Kirmse MD, Robert M Kacmarek PhD RRT, Sylvester Barker LPN, Harold Mang MD (University of Erlangen, *Nürnberg, Germany*), William Kimball PhD MD, Massachusetts General Hospital, *Boston, Massachusetts.*

Controversy exists regarding use of applied ($PEEP_A$) vs $PEEP_I$ in the management of ARDS (Respir Care 1990;35:945). We questioned whether $PEEP_A$ and $PEEP_I$ would affect local FRC, V_T, and dynamic PEEP ($PEEP_d$) similarly. **Methods:** We performed our evaluation using a 4-chamber lung model (LM) created from 2 Michigan Instrument TTLs in parallel. The time constant (TC) of the total LM was 0.59 s, TCs of each chamber were 1.0 s (COPD), 0.093 s (ARDS), 0.52 s (Norm 1), 0.53 s (Norm 2). At the simulated trachea and at the entrance of each chamber, a Hans Rudolph 3700 pneumotachograph and a Validyne pressure transducer MP-45-32-871 ± 100 cm H_2O were positioned. A total static PEEP of 12.5 cm H_2O was established at the trachea during the application of pressure control (PC) ventilation at 1:3 and 3:1 I:E, with a 7200 ventilator. Rate and V_T were constant. Data were acquired and analyzed with a Dataq CODAS system. **Results:**

	COPD	Norm 1	Norm 2	ARDS
PC 1:3, FRC (mL)	836.0 (13.191)*	553.8 (3.962)†	558.4 (3.567)†	95.4 (0.547)†
PC 3:1, FRC (mL)	838.8 (3.962)	590.8 (10.425)†	590.6 (2.880)†	80.6 (0.547)†
PC 1:3, V_T (mL)	316.1 (0.316)	255.8 (0.422)	285.6 (0.516)†	74.0 (0.044)
PC 3:1, V_T (mL)	308.8 (3.011)	260.9 (1.595)	305.3 (1.636)†	75.2 (0.788)

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	COPD	Norm 1	Norm 2	ARDS
PC 1:3, $PEEP_d$ (cm H_2O)	12.20 (0.025)†	12.29 (0.021)	12.18 (0.017)	12.44 (0.032)
PC 3:1, $PEEP_d$ (cm H_2O)	13.09 (0.029)†	12.50 (0.043)	12.11 (0.042)	12.11 (0.067)

*Each value is the mean (SD) of 5 breaths.

†$p < 0.01$ t test and $\geq 5\%$ variation.

Conclusion: The distribution of FRC differed across compartments and I:Es, and V_T differed across compartments but not across I:Es, while local $PEEP_d$ demonstrated no clinically significant differences across I:Es. It does not appear that an I:E of 3:1 shows any advantage over 1:3 in distribution of lung volume or distribution of applied PEEP. (OF-92-104)

Effect of Pressure (PC) vs Volume Control (VC) Inverse Ratio Ventilation on Local Distribution of Volume and Pressure in a Four-Chamber Lung Model—Max Kirmse MD, Robert M Kacmarek PhD RRT, Sylvester Barker LPN, Harold Mang MD (University of Erlangen, *Nürnberg, Germany*), William Kimball MD PhD, Massachusetts General Hospital, *Boston, Massachusetts.*

Many techniques are available to apply inverse ratio ventilation (IRV) using either volume or pressure control. We questioned whether the approach used would affect local FRC, V_T, and dynamic PEEP ($PEEP_d$) in a 4-chamber lung model created from 2 Michigan Instrument TTLs in parallel. **Methods:** The time constant (TC) of the total system was 0.59 s, TCs of each chamber were 1.0 s (COPD), 0.093 s (ARDS), 0.52 s (Norm 1), 0.53 s (Norm 2). At the simulated trachea and at the entrance of each chamber, a Hans Rudolph 3700 pneumotachograph and a Validyne pressure transducer MP-45-32-871 ± 100 cm H_2O were positioned. At a constant rate (12/min), V_T (925 mL), total PEEP (12.5 cm H_2O), and I:E (3:1) we evaluated the local FRC, V_T, and $PEEP_d$ during PC, VC square-wave flow with a pressure plateau (VPS) and without (VCS), and VC decelerating flow with a pressure plateau (VPD) and without (VCD), using a 7200 ventilator. Five breaths at each setting were analyzed using a Dataq CODAS system. **Results:** V_T in the ARDS compartment was smallest with VPD [68.8 (0.422)] and largest with PCV [75.2 (0.789)]. FRC was lowest in the COPD compartment during VPD [790 (4.848)] and largest during VCS [863.8 (3.962)], whereas in the ARDS compartment FRC was lowest during VPD [93.2 (0.442)] and largest during VCS [107 (3.808)]. $PEEP_d$ was lowest in the COPD compartment during VPD [12.57 (0.0178)] and largest during VC [13.29 (0.337)], whereas in the ARDS compartment $PEEP_d$ was lowest with VPD [11.55 (0.269)] and largest with VCS [12.19 (0.047)]. All differences were significant ($p < 0.01$ ANOVA) and represent a variance greater than 5%. **Conclusion:** Although statistically significant differences were noted across approaches, most of these differences do not appear to be clinically relevant. (OF-92-105)

Inspiratory Work of Breathing Imposed (WOB_I) by the BiPAP Ventilator—Christopher Hirsch MPH RRT, Sylvester Barker LPN, Robert M Kacmarek PhD RRT, Massachusetts General Hospital, *Boston;* Peggi Robart RRT, Chartwell Home Health Care, *Waltham—Massachusetts.*

The use of the Respironics BiPAP ventilator has become commonplace for the application of noninvasive mechanical ventilatory support. Because it incorporates a fixed, constant system leak, we questioned whether alterations in inspiratory (IPAP) and expiratory (EPAP) pressure settings, or other alterations in the delivery system, would affect WOB_I. **Methods:** All evaluations were performed on a 'spontaneously breathing' lung model, consisting of a Michigan Instruments TTL, powered by a Puritan-Bennett 7200 ventilator. Measurements were made with a Hans Rudolph 3700 pneumotachograph and a Validyne MP-45-32-871 ± 100 cm H_2O differential pressure transducer. Data were analyzed with a Dataq CODAS data acquisition system. Measurements of WOB_I were made on 3 different BiPAP units at various pressure settings, with smooth-bore (S) and corrugated (C) tubing, with a system humidifier (H), and without a humidifier (N), during the addition of O_2 at the unit (O_2 U), and at the patient mask (O_2 M), as well as the creation of an additional system leak (4.08-mm orifice, L). **Results:** All results are WOB_I at 14 cm H_2O IPAP/4 cm H_2O EPAP, and are the mean and standard deviation of 15 breaths (5 from each BiPAP unit) in joules/L.

S, N	C, N	S, H	C, H	S, O_2 M
0.01028 (0.00001)	0.01051 (0.00001)	0.01294 (0.00001)	0.01218 (0.00001)	0.01011 (0.00002)

S, O_2 U	C, O_2 M	C, O_2 U	S, L	C, L
0.01112 (0.00001)	0.01150 (0.00001)	0.01147 (0.00001)	0.01232 (0.00008)	0.02066 (0.00014)*

*$p < 0.01$ t test vs S, N. Significant differences were also noted among the 3 BiPAPs at each condition, $p < 0.05$ by ANOVA

Conclusion: Minimal WOB is imposed by BiPAP, which does vary from unit to unit but not in a clinically important manner. Alterations in the standard BiPAP setup does not increase WOB_I except when an additional leak is created in conjunction with corrugated tubing, although this is not a clinically significant change. (OF-92-106)

Aerosol Delivery via MDI and Holding Chamber during Mechanical Ventilation (MV)—Thomas A Barnes EdD RRT, Nancy Chen PhD, Northeastern University, *Boston, Massachusetts.*

We compared amounts of MDI-generated respirable (1-4.5 μm) aerosol penetrating a 9-mm anatomically shaped ETT, using the Monaghan disposable holding chamber (Aerochamber, HC) with and without its valve. **Method:** HC placed between the Y-connector and ETT was used with an Intertech Volume Ventilator Circuit model 003280 attached to a Bennett MA-1.

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A Bennett Cascade I humidified inspiratory gas heated to 33°C (measured proximal to Y-connector). The ventilator delivered 1 L into the circuit at flow of 30 L/min. V_T and $\dot{V}$ were verified by a calibrated Timeter RT-200. The calibrated 6-stage cascade impactor, California Measurements Model AS-6 (through which air was drawn at 12.5 L/min), used to characterize aerosol penetrating ETT was fitted with an evaporation chamber (EC). EC was modified from a 3-L round-bottom distillation bottle (diameter 16 cm) by addition of another port. HC was tested with and without its valve using a previously described nonaqueous suspension aerosol (Pharm Res 1988;5:36-39) containing 1.09% micronized disodium fluorescein (DF) as the model drug, stabilized by 1.0% sorbitan trioleate in a blend of fluorocarbons (29.37% and 68.53% Freon 11 and 12, respectively). A 50 μL metering valve (Bespak) was used throughout and each spray contained 754 μg of DF. Actual amount of DF delivered through stem orifice was corrected for actual sample weight. The MDI was actuated midway through a 2-s inspiration emitting the spray into a continuous gas flow. Following 10 actuations spaced at 6-s intervals (cannister shaken vigorously after every two puffs), DF deposited in the HC, ETT, EC, and each stage of cascade impactor was determined spectrophotometrically at 488.5 nm. **Results:**

	% Output from ETT*			
Aerochamber	Total	EC	Impactor	Respirable (1-4.5 μm)*†
With valve	0.98 (0.17)	0.28 (0.14)	0.70 (0.06)	0.64 (0.05)
Without valve	3.19 (0.26)	0.85 (0.14)	2.33 (0.29)	1.99 (0.26)

	% Elsewhere*	
Aerochamber	ETT	Holding Chamber
With valve	4.00 (0.81)	94.96 (0.71)
Without valve	10.58 (0.40)	86.15 (0.38)

*Percentage of dose emitted from 50-μL metering valve. Mean (SD) of three replicates.

†The mass median aerodynamic diameter (SD) was determined to be 1.92 (0.17) for Aerochamber with valve and 2.37 (0.05) for Aerochamber without valve.

Significant differences existed between total and respirable aerosol penetrating ETT when Aerochamber was compared with and without its valve (ANOVA, $p < 0.001$). Signficant differences in aerosol impacting in HC and ETT existed with and without valve (ANOVA, $p < 0.001$). **Conclusion:** Aerochamber appears to deliver more respirable aerosol when HC valve is removed. More study is needed to determine the efficacy of valved MDI HCs for delivery of aerosols during MV. (OF-92-120)

Comparison of Pressure Controlled Ventilation (PCV) and Volume Controlled Ventilation (VCV) with a Descending Flow Waveform—Robert S Campbell RRT, Richard D Branson RRT, Daniel J Johnson MD, David T Porembka DO, Kenneth Davis Jr MD. University of Cincinnati Medical Center, *Cincinnati, Ohio.*

PCV has been reported to improve gas exchange compared to VCV with rectangular-flow waveform. We compared PCV to VCV with a descending-flow waveform in 15 mechanically ventilated patients requiring ≥ 8 cm H_2O PEEP to maintain a $P_{aO_2}/F_{IO_2} > 200$. All patients were initially ventilated in VCV with V_T of 12 mL/kg. Rate was set to maintain normocarbia, pH > 7.30, and spontaneous f < 20 bpm. Pressure and volume were measured at the proximal airway with a Bicore pulmonary monitor. After 2 h, arterial and mixed-venous blood gases were drawn. Ventilator variables, systemic and pulmonary blood pressures, and cardiac output were measured and recorded. Patients were then placed on PCV with pressure limit set to equal PIP during VCV. Rate, inspiratory time, and I:E were held constant. Results are mean (SD).

	PCV	VCV
PIP (cm H_2O)	52 (17)	52 (17)
P_{aw} (cm H_2O)	21.6 (4.8)	20.3 (5.0)
V_T (mL)	970 (125)	920 (118)
P_{aO_2} (torr)	103 (29)	98 (34)
P_{aCO_2} (torr)	38 (7.3)	39 (6.7)
$\dot{Q}s/\dot{Q}t$ (%)	22.1 (8.8)	24.8 (10)
Cl (L/min/m^2)	3.6 (1.1)	3.5 (1.5)

Inspiratory time was 1.52 (0.45), f was 9 (3), mean I:E was 1:3.8, and PEEP was 11 (2). There were no statistically significant differences in any measured variable. V_T and $\bar{P}_{aw}$ were slightly higher with PCV. This may be due to faster initial flow seen in PCV, which results in a quicker rise to PIP. Our results demonstrate that PCV offers no advantage over VCV with a descending-flow waveform with respect to gas exchange, airway pressures, and hemodynamics when PIP, inspiratory time, and I:E are held constant. VCV may be advantageous due to delivery of a constant volume in the face of changing lung compliance. (OF-92-150)

The Addition of Sighs during Pressure Support Ventilation (PSV): Is There a Benefit?—Richard D Branson RRT, Robert S Campbell RRT, Kenneth Davis Jr MD, Daniel J Johnson MD. University of Cincinnati Medical Center, *Cincinnati, Ohio.*

The use of a sigh breath during volume-controlled ventilation with V_Ts of 10-15 mL/kg has proven to be of no benefit. We postulated that during PSV, as PIP is decreased and V_T falls, sighs may be beneficial. 10 patients being weaned using PSV were studied. During a 4-h period patient f, V_T, $\dot{V}_E$, and airway pressures were continuously monitored by a Bicore CP-100 monitor. Every 30 min, an average of these variables was compiled from a 5-min printout. At the end of period, an ABG was drawn and analyzed at patient temperature. Sigh breaths were then programmed into the 7200ae ventilator using 6 sighs/h, 2 sighs/event, at a volume of 12 mL/kg. A 4-h period using sighs was accomplished, and the same data recorded. A final 4-hour period without sighs was then performed in the same manner

as the initial panel. PSV level, PEEP, and F_{IO_2} were held constant throughout the study. Results are mean (SD).

	No Sighs	Sighs	No Sighs
P_aO_2 (torr)	91 (12)	100 (19)	102 (20)
P_aCO_2 (torr)	43 (2)	43 (2)	41 (3)
f (b/min)	23 (5)	23 (6)	24 (6)
V_E (L/min)	9.3 (2.1)	9.0 (2.5)	9.2 (1.8)
V_T (mL)	411 (116)	403 (102)	407 (117)
P_{aw} (cm H_2O)	10.2 (1.7)	10. 8 (1.9)	10.1 (1.8)

Mean PSV was 16.5 (3.7) providing a V_T of 4.7 mL/kg. There were no statistically significant differences in any measured variable. We conclude that sigh breaths provide no measurable benefit during PSV at normal tidal volumes. It appears that it is indeed time to "kiss the sigh goodbye." (OF-92-151)

Gaussian Method To Improve Work of Breathing Variability—Marcy F Petrini PhD, Jeffrey N Evans MD, Mark A Wall MBA RRT, Frederick T Duggan MD, J Keith Mansel MD, Joe R Norman MD. University of Mississippi Medical Center, *Jackson, Mississippi.*

The intrapatient variability is an important variable when work of breathing (WOB) under different ventilatory modes is compared. The variability is the result of normal variation in the patient's ability to do work and thus can itself be a useful measure; but it can be increased by additional ventilatory maneuvers such as coughing or artifactual changes in esophageal pressure with swallowing, that are superimposed on amount of work performed by the patient during normal breaths. We developed an objective method that separates WOB of normal breaths from that caused by extraordinary ventilatory maneuvers and swallowing, using breath-by-breath data from a Bicore Pulmonary Monitor CP-100. The method uses the difference (P) in esophageal (P_e) and alveolar (P_a) pressures provided by the CP-100 (change in each during a breath); frequency distribution of P is modeled with a non-linear best fit of a unimodal Gaussian curve that calculates mean and standard deviation (SD). Breaths falling within 2 SDs are then used to determine the patient's mean work and its true variability from data provided by the CP-100. Because this monitor uses P_e and P_a to calculate and partition work of breathing of patient (WOB_p) and of ventilator (WOB_v), we analyzed data from different ventilatory modes. In 3 spontaneously breathing normals, the coefficient of variation (CV) of WOB_p dropped from 43% to 17% when Gaussian method was employed; during volume control, with 5 patients performing minimal work, WOB_v CV dropped by 2%; during pressure support in 5 patients, WOB_p CV dropped from 254% to 51% and WOB_v CV dropped by 3%. In 2 patients on Down's Flow Generator CPAP, WOB_p CV dropped from 62% to 35%, and from 62% to 16% on ventilator CPAP. We believe that this method helps us obtain a clinical picture that more closely resembles the patient's true work of breathing. (OF-92-156)

Neonatal, Infant, and Pediatric Pulmonary Function Testing

Asthma Misdiagnosed: A Case Report—Sandra E King RRT, Pamela Leisenring RRT, Robert Hughes Warren MD. Arkansas Children's Hospital, *Little Rock, Arkansas.*

Vascular ring is a rare congenital anomaly that can produce tracheoesophageal compression resulting in various degrees of respiratory compromise. It is commonly diagnosed in early infancy and is less likely to be considered in the older patient presenting with respiratory symptoms. Flow-volume loop configuration is essential in evaluating fixed airway obstruction as seen in vascular ring. **Case Summary:** A 16-year-old Caucasian boy was referred to Arkansas Children's Hospital for evaluation of wheezing (present since 18 mo of age) and decreased exercise tolerance. Asthma had been diagnosed at age 13 based on volume-time curves suggesting obstruction. Aggressive bronchodilator and steroid therapy provided minimal or no improvement. Respiratory symptoms had progressed during the ensuing 3 years, resulting in increased shortness of breath and lethargy during exercise. Physical exam was normal. Medications consisted of cromolyn sodium (Intal) and albuterol aerosol tid; Aerobid 5 puffs bid; Proventil rotacaps and Intal MDI prior to exercise. Flow-volume-loop values showed airflow limitation in the large and small airways (PEFR 4.73 L/s, 49% of predicted; PIFR 4.67 L/s; FEF_{25-75} 3.18 L/s, 50% of predicted; FIF_{50} 3.33 L/s). Loop configuration was classic for fixed airway obstruction. Routine chest x-ray suggested a double aortic arch. Barium swallow showed a focal narrowing of the esophagus at level of right aortic arch. Subsequent cardiac catheterization confirmed a vascular ring with tracheal and esophageal compression, which was surgically repaired without complication. Flow-volume-loop data 9 months after repair revealed no significant changes (PEFR 52%, FEF_{25-75} 62%). Patient is now being evaluated for tracheal reconstruction. **Conclusion:** Congenital vascular anomaly produced symptoms that were misdiagnosed as asthma. While volume-time curves suggested airflow limitation, they did not provide information for determining specifically a fixed airway obstruction. Shape of the flow-volume loop, with no response to bronchodilator, strongly suggested this type of obstruction and led to correct diagnosis. Flow-volume loop is a valuable tool in initial evaluation of wheezing and exercise intolerance. (OF-92-021)

Pulmonary Function Assessment in Diaphragm Dysfunction: Case Report—Karen Turrentine RRT, Sandra E King RRT, Sheila Alderson RRT, Robert Hughes Warren MD. Arkansas Children's Hospital, *Little Rock, Arkansas.*

Respiratory inductive plethysmography (RIP) can measure breathing patterns noninvasively by transmitting rib-cage (RC) and abdomen (AB) compartment changes associated with ventilation through oscillator circuitry. FRC by nitrogen washout has been proven method of obtaining lung volumes in younger infant and child. We obtained RIP and FRC data to assess functional improvement obtained following plication of di-

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aphragm. **Case Report:** A 5-month-old fraternal twin delivered by C-section to a 44-year-old G9 P5 Caucasian woman was referred to Arkansas Children's Hospital for respiratory problems since birth. Chest x-ray revealed an elevated diaphragm with suspected eventration. Abdominal ultrasound confirmed high right hemidiaphragm with paradoxical motion during respiration. Surgical plication of diaphragm was performed without complications. RIP and FRC by nitrogen washout were performed pre- and post-surgery. **Results:**

	Pre	Post
FRC (mL)	69.5	193.4
FRC/kg (mL/kg)	8.8	19.0
Compliance (mL/cm H_2O)	19.9	24.3
Resistance (cm H_2O/mL/s)	0.025	0.024
Phase Angle (°)	37.8	12.7
MCA/V_T*	1.14	1.04
%RC/V_T	10.5	29.4

*MCA = maximal compartmental amplitude.

Preoperative FRC of 8.8 mL/kg was 45% of predicted. Following surgical repair, FRC improved to 100% of predicted. Compliance and resistance were within normal limits pre- and post-surgery. Phase angle decreased from 37.8°, indicating asynchrony, to a value of 12.7, indicating a normal rib-cage and abdominal breathing pattern. Preoperative MCA/V_T was 1.14, also indicating rib-cage and abdomen asynchrony. Postoperative value for MCA/V_T was 1.04, which is within normal limits. %RC/V_T before surgery was low at 10.5% and improved to normal value of 29.2%. **Conclusion:** Surgical plication of the diaphragm is commonly performed in infants and small children. This case report demonstrates value of comprehensive pulmonary function testing including RIP in determining degree of preoperative pulmonary dysfunction and resultant improvement that can be obtained with surgical procedure. (OF-92-022)

Case Summary: The Use of Partial Expiratory Flow-Volume Loop To Diagnose Tracheal and Bronchial Abnormalities—Catherine C Smith RRT, Robert L Zanni MD. Monmouth Medical Center, *Long Branch, New Jersey.*

A 3-mo-old boy was admitted to our pediatric unit with a persistent raspy cough that was spastic in character and similar to pertussis. The cough had developed at 1.5 mo of age. Prior to that he had been in a normal state of health. He had been seen several times by his pediatrician, but no abnormalities were found. He received one course of Pediazole, with no improvement. On admission, the physical exam showed him to be active, alert, neurologically intact, and in no acute distress. He was then referred to our pediatric pulmonologist who ordered pulmonary function testing and a pH probe to test for gastroesophageal reflux. The pH probe was positive for reflux. The flow-volume-loop portion of the partial expiratory flow-volume loop suggested intrathoracic compression, and airway closure was noted twice prior to completion of peak flow portion of maximal expiratory flow. V_T and $\dot{V}_E$ were in normal range, but $\dot{V}_{max}$ FRC was only 59% of predicted prior to a high-flow nebulizer treatment with albuterol and 41% of predicted after treatment. Flexible fiberoptic bronchoscopy revealed evidence of tracheobronchomalacia with stenosis of left-main bronchus. Tracheomalacia was mild in lower portion of trachea. Vocal chords and main-stem bronchus were normal. Upper portion of the main-stem bronchus was stenosed (75% obstruction). Patient was sent home on gastroesophageal reflux medications and aerosol treatments. **Conclusion:** Our experience suggests that infant PFT can be a useful diagnostic tool in the diagnosis of tracheal and bronchial abnormalities. Infant PFT may be useful as a screening tool prior to bronchoscopy. (OF-92-053)

Flow-Volume (FVL) and Pressure-Volume (PVL) Loops for Different Modes of Pediatric Mechanical Ventilation: A Simulation—Patricia Walters RPFT RRT, Lela Brink MD. Children's Medical Center, *Dallas, Texas.*

FVL and PVL are used to evaluate ventilation in children. Mechanical ventilators alter delivery of inspiratory gases by changes in pressure-time (PT) or flow-time (FT) variables. This study was designed to evaluate effects that changes in ventilatory mode have on FVL and PVL. A Michigan Instruments Infant Training Test Lung (TTL) was set for normal airway resistance. Compliance was set at either normal compliance (NC) (1 mL/cm H_2O/kg) or low compliance (LC) (0.3 mL/cm H_2O/kg). A Siemens 900C ventilator was interfaced to TTL using a 4-mm Portex endotracheal tube cut to 17 cm in length and a dry, room temperature Baxter #1212-H11 pediatric ventilator circuit. The 900C was used to ventilate TTL in volume-controlled (VC), pressure-controlled (PC), and pressure support (PS) modes to evaluate effect these changes in inspiratory PT and FT waveform would have on PVL and FVL. The 2600 with a 30 L/min pneumotachometer was calibrated to ambient conditions. 900C was set for F_{IO_2} of 0.60, working pressure of 20 cm H_2O over peak pressure, and V_T of 15 mL/kg, f 20, inspiratory time 0.75 s, PEEP 2. TTL was set as a single test compartment with the second compartment triggered by a Bird Mark VII to simulate spontaneous breaths for PS. PVL & FVL data were collected for NC settings in all modes. LC settings data was collected in PC & VC modes only. Results are shown in table as % change from readings on 900C digital readout. PVL were all rectangular. FVL showed high elastic recoil that invalidated the standard variables used to monitor small airway obstruction. PC and PS FVL were sine in appearance whereas VC was square.

	VC (NC)	VC (LC)	PC (NC)	PC (LC)	PS (NC)
V_T	25%	49%	29%	47%	31%
MAP	13%	100%	92%	90%	276%

We conclude discrepancy between settings on 900C and measures by 2600 were attributable to (1) 900C measures ATPS and 2600 BTPS; (2) ventilator-circuit compressible-volume loss for all modes (which increases as lung compliance decreases) and this volume loss is not measured by 900C; (3)

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900C measurements inside ventilator are less reflective of delivered ventilation than measures by 2600 done at patient Y. The inspiratory limb of FVL reflects flow characteristics of ventilatory mode on 900C and may give a false impression of inspiratory flow limitation and small airways obstruction. Changes in FVL and PVL may help determine optimal ventilatory settings as patient pathology changes. (OF-92-142)

Does Burn Size Influence Cardiopulmonary Performance in Children Convalescing from Thermal Injury?—Ronald P Mleak RCP RRT, Manu H Desai MD, Elizabeth Robinson CRTT, James Richardson RRT, Robert L McCauley MD, Martin C Robson MD, David N Herndon, Shriners Burn Institute, *Galveston, Texas.*

Cardiopulmonary performance levels in children convalescing from thermal injury are unknown. It has been postulated that due to extensive destruction of skin and appendages following thermal injury, the thermoregulatory control mechanism would be impaired and patients would be intolerant to prolonged work. Previous studies demonstrate that during work in a hot climate, patients with an extensively healed burn react with an excessive rise in body temperature and thus decreased work ability. **Purpose**: The purpose of this study was to investigate effects of burn size on cardiopulmonary performance and to study changes in body temperature during exercise testing. **Methods**: Cardiopulmonary stress tests were completed in 32 children with a mean (SE) time postburn of 2.3 (1.5) years and mean (SE) size burn of 44 (23) % TBSA (total body surface area). (18 patients had sustained inhalation injury, 14 had not). Exercise variables included $\dot{V}_E$, V_T, RR, V_D/V_T%, HR, and work stage achieved. (Bruce protocol, with speed and grade increases every 3 min.) Temperature monitoring included core, burn scar, and normal skin. **Statistical Analysis**: Statistical significance of difference was tested with analysis of variance and Student's paired *t* test. All data are reported as mean (SE). **Results**:

Demographics

Age	Sex	Wt	Ht	Race	% TBSA	% 3rd
11.9 (4)	25 M 7 F	45 (20)	148 (22)	24 C, 6 B, 2 H	44 (23)	29 (24)

Exercise Variables (% Pred)

$\dot{V}_E$	V_T	RR	V_D/V_T	% HR	Stage Achieved
94 (34)	90 (38)	124 (45)	240 (34)	90 (8)	4 (0.6)

Temperature Variables

Pre	During	Max	Pre	During	Max	Pre	During	Max
36.9 (1)	36.8 (1)	37 (1)	32.9 (1)	32.7 (1.8)	32.7 (1.7)	32.6 (1.2)	32.6 (1.5)	32.6 (1.6)

Conclusion: Our data indicate all patients reached same endurance level, thus burn size in itself does not influence cardiopulmonary performance. Additionally, in a temperature-controlled environment, adequate heat dissipation in burned children can be maintained during exercise testing without an excessive rise in body temperature. (OF-92-159)

Ventilatory Limitation to Exercise In Burned Children—Ronald P Mleak RCP RRT, Manu H Desai MD, Elizabeth Robinson CRTT, James Richardson RRT, Robert L McCauley MD, Martin C Robson MD, David N Herndon, Shriners Burn Institute, *Galveston, Texas.*

Cardiopulmonary stress testing allows evaluation of cardiac as well as pulmonary limitations to exercise. This physiologic response has not been previously reported in children following thermal injury. Our investigation, part of a longitudinal assessment, sought to evaluate residual cardiopulmonary impairment in children convalescing from severe burns. **Methods**: 40 children with mean (SE) postburn injury of 2.6 (1.9) years and a mean burn size of 44 (22) % were evaluated by pulmonary function studies and cardiac stress testing (14 with inhalation injury, 26 without). Cardiopulmonary variables studied during exercise were $\dot{V}_E$, V_T RR, V_D/V_T, WR, $\dot{V}_{O_2}$, RQ, HR, HR reserve, O_2 pulse, maximum stage achieved. **Statistical Analysis**: Statistical significance of difference was tested with analysis of variance and the Student's paired *t* test. Data reported are mean (SE). **Results**:

Demographics

Age	Sex	Wt (kg)	Ht (cm)	Race	% TBSA	% 3rd
11.9 (4.6)	29 M, 11 F	44.9 (20.0)	144 (30)	29 C, 8 B, 3 H	44 (22)	27 (23)

Exercise Variables (% Pred)

$\dot{V}_E$	V_T	RR	V_D/V_T	Stage Achieved
105 (61)	98 (46)	123 (45)	245 (45)	4.1 (0.6)

Metabolic & Cardiac Variables (& Predicted)

WR	VO_2	RQ	HR	HR Reserve	O_2 Pulse
134 (25)	73.9 (22.0)	111 (31)	89 (7)	20 (—)	85 (29)

Spirometry & Lung Volumes (& Predicted)

FVC	FEV_1	FEF_{25-75}	FEV_1/FVC	PEF	MVV	VC	TLC	VC
93 (13)	94 (13)	89 (23)	97 (6)	91 (21)	83 (13)	99 (13)	100 (17)	99 (13)

Test	Inhalation Injuries (n = 14)	Non-Inhalation Injuries (n = 26)
$\dot{V}_E$	124 (95)	96 (29)
V_T	91 (35)	101 (50)
RR	140 (52)	100 (38)
V_D/V_T	259 (54)	239 (34)
Stage achieved	3.1 (0.8)	3.1 (0.8)

*$p < 0.05$.

Conclusion: Resting spirometry and lung volumes showed 40% incidence of abnormal lung function, predominantly obstructive and restrictive disease. Cardiopulmonary stress testing revealed increased V_D/V_T and < normal $\dot{V}_{O_2max}$. Data indicate that children who survive severe thermal injury may show signs of some ventilatory limitations to exercise. (OF-92-160)

Mechanical Ventilation Weaning Criteria by Pulmonary Function Testing of a Cystic Fibrosis Patient—Patricia Walters RPFT RRT, Lela Brink MD, Children's Medical Center of Dallas, *Dallas, Texas.*

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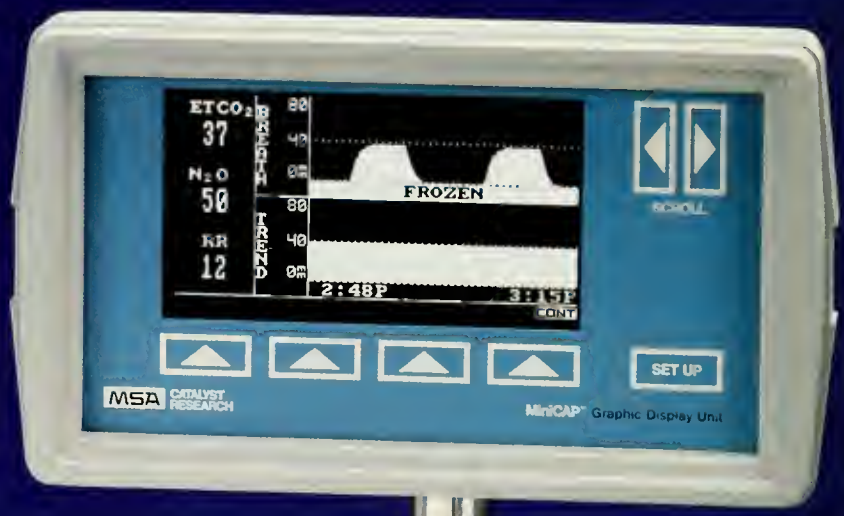

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The SensorMedics 2600 Pediatric Pulmonary Cart (2600) performs functional residual capacity (FRC) and flow-volume loops (FVL) for tidal breaths with a 100 L/min pneumotachometer for both ventilator and non-ventilator sedated pediatric patients. We proposed that a cooperative ventilator patient with cuffed tracheostomy tube could use the 2600 to perform forced vital capacity (FVC) as long as expiratory flows did not exceed 100 L/min or 1.67 L/s. We report such a case in which lung function was used to predict successful withdrawal from mechanical ventilation (MV). An 18-year-old man (149 cm tall, 40 kg, with history of cystic fibrosis, diabetes mellitus, esophageal varices, anemia, chronic aspergillus and pseudomonas infections) underwent surgery for orthotopic liver and simultaneous kidney transplantation. His postoperative course was complicated by recurrent renal failure, nephrectomy and dialysis, exploratory laparotomy × 4 for massive retroperitoneal hematoma, abdominal fistula, massive hemoptysis and epistaxis secondary to herpes infection, and multiple septic episodes. 15 wks after initial surgery, patient remained on MV with pressure support for delivered V_T 8 mL/kg, O_2 25%, and PEEP 4. Infections were under control at this point, and healing was noted at wound sites. Also, this intuitive patient stated he wanted to come off MV. He was asked to perform FRC and FVC with the 2600. Measures for TBL convert the following FVC measures: $\dot{V}_E$ = FVC, V_I = inspiratory capacity (IC), PTEF = peak expiratory flow rate, TEF-50 = forced expiratory flow 50%, TEF-25 = forced expiratory flow 75%. FVC measures came within 20-25% of pre-surgery measures with V_T 30% of FVC, FRC 122% of predicted, IC 15 mL/kg. These measures were thought to be acceptable for withdrawal of MV, and patient was placed on incremental T-bar trials. 4 days later all MV was successfully withdrawn. 6 weeks later, patient was transferred to general floor care and routine FVC measures were within 10% of weaning criteria. The 2600 provided a safe, effective tool for monitoring FVC measures for weaning criteria in this very difficult patient. (OF-92-165)

Functional Residual Capacity (FRC) Measurement for Older Pediatric Ventilator Patients Using the SensorMedics 2600 Pediatric Pulmonary Cart—Patricia Walters RPFT RRT, Lela Brink MD. Children's Medical Center of Dallas, *Dallas, Texas.*

The 2600 measures FRC for pediatric ventilator patients via N_2 washout with a constant-flow open circuit and fast-response ultraviolet N_2 analyzer (Gerhardt, 1986). A specific constant flow of O_2 is used to hand-ventilate a patient with an anesthesia bag through a switch-in valve that allows the patient to go from mechanical to manual ventilation at end-exhalation. All O_2 flow to the anesthesia bag is returned to the 2600 mixing chamber. The N_2 analyzer is calibrated against room air and 100% O_2 and high- and low-flow (defined as high and low volume relative to patient's predicted FRC) from calibration syringe pumped repeatedly over time against O_2 flow until all N_2 is washed from syringe. Because O_2 flow is kept constant during calibration and testing, washout N_2 volume is integral of N_2 concentration. The 2600 software limits washout time to 2 min 20 s. No more than 7-8 L/min O_2 is needed to ventilate a patient with this technique; however, this may not be enough flow to achieve high-flow calibration. In order to provide testing to older pediatric patients, we designed and tested a split O_2 flow circuit, finding that 20 L/min O_2 was ample for high flow calibration with a 3-L syringe within the time limit. We used 2 O_2 flowmeters set for 7 and 13 L/min each (total flow 20), linked with O_2 tubing then placed in the routine position for calibration. For patient testing, the 2 flows were separated; 13 L/min flow was attached to a T-piece connected at mixing chamber inlet; 7 L/min flow was connected to anesthesia bag in routine fashion. We tested this modification by hand-ventilating a test lung with known FRC of 1.846 L. 10 trials produced a mean (SD) of 1.801 (0.21) L or within 2.5% of known FRC. We have used this modification on 14 patients (ages 7-19 y) without difficulty. Test results remain reproducible (coefficient of variation < 6%) for each patient. Cost for the extra flowmeter and Y- and T-pieces is minimal. We concluded this to be an effective means of FRC measurement for older pediatric ventilator patients. (OF-92-168)

Partial Forced Expiratory Flow-Volume Measurement, Radiographic Severity Score, and Bronchodilator Response in Infants with Chronic Lung Disease—Theresa Wahlig MD, Dennis Bing RRT, Keith Holloman RRT, Mark C Mammel MD, Children's Hospital, *St Paul*; Roy Maynard MD, University of Minnesota, *Minneapolis—Minnesota.*

The purpose of this study was to compare several methods of evaluating severity of chronic lung disease in infants. We performed partial forced expiratory flow-volume (PEFV) studies and determined $\dot{V}_{max}$ FRC in 43 infants with bronchopulmonary dysplasia (BPD) just prior to NICU discharge. We defined BPD using the criteria of Bancalari: (1) mechanical ventilation during the first week of life, (2) clinical signs of chronic respiratory disease, (3) 28 or more days of supplemental O_2 therapy, (4) characteristic chest x-ray findings. At birth, weights were [mean (SD)] 1,088 (534) g, range 420-3,000 g; gestational age (GA) 27.9 (3.4) wks, range 23-36 wks. At study, infants weighed 2,534 (562) g, range 1,750-3,800 g, and had adjusted ages of 39.9 (4.1) wks. Duration of MV was 23.4 (20) d, range 1-82 d. $\dot{V}_{max}$ FRC values ranged from 13.5% to 159% of predicted normals [mean (SD) 59.1% (44.5]. We found significant expiratory flow limitation ($\dot{V}_{max}$ FRC < 60% of normal) in 29 infants (67%). We compared expiratory flow limitation to birthweight, gestational age, test weight, and durations of MV and O_2 therapy using regression analysis. $\dot{V}_{max}$ FRC correlated with increased GA ($r = 0.33$, $p = 0.03$) and increased weight ($r = 0.48$, $p = 0.001$). In 38 infants with low initial $\dot{V}_{max}$ FRC, a second test was done after aerosolized albuterol treatment. 27 of 38 (71%) had positive responses (> 20% increase in $\dot{V}_{max}$ FRC). 5 (13%) had negative responses (> 20% decrease in $\dot{V}_{max}$ FRC). Chest x-rays obtained at 4 weeks of age were scored for degree of chronic lung injury (AJDC 1984;138:583). Scores were compared to $\dot{V}_{max}$ FRC, albuterol response, and to days of O_2 therapy using regression analysis. Radiographic severity scores did not correlate with

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either degree of flow limitation ($r = 0.137$) or albuterol response ($r = 0.188$). Scores did correlate with days of O_2 therapy ($r = 0.37$, $p = 0.02$). Our data show (1) expiratory flow limitation at discharge, nearly always present in these previously ventilated infants, is inversely related to gestational age and weights; (2) response to bronchodilators, though common, is unpredictable; (3) in BPD patients, radiographic severity scores and duration of O_2 therapy are related, but neither predict degree of flow limitation or bronchodilator response. (OF-92-190)

Use of the Occlusion Technique (OT) To Measure Passive Mechanics in Pediatric Ventilator Patients—Gary D Williams MB BS, Lela Brink MD, Patricia Walters RPFT RRT. Children's Medical Center of Dallas, *Dallas, Texas.*

OT is used to obtain passive lung mechanics measurements in intubated ventilated neonates. A static pressure-volume curve is described by occlusion of airway at known lung volume and recording airway pressure during a passive exhalation. Slope of curve represents static compliance of lung if active chest-wall recoil is eliminated. In spontaneously breathing neonates, apnea can be induced by airway occlusion at lung volumes above FRC, that is, a Hering-Breuer reflex (HBR) is present. We propose that older patients can be evaluated using OT if adequate chest-wall relaxation can be assured either by documentation of presence of HBR or by achieving adequate pharmacologic paralysis of respiratory muscles. Patients were either sedated (S), sedated and paralyzed (P), or neither receiving sedation nor paralysis (N) for mechanical ventilation. All studies were done using a computerized pediatric pulmonary function cart (SensorMedics 2600) with an appropriate-sized pneumotachometer (Hans Rudolph) and pneumatic occlusion valve for passive mechanics. In spontaneously breathing patients, after a minimum of 3 spontaneous breaths, occlusion valve was switched on and at end of inspiration, valve occludes airway, remaining closed until a negative airway pressure occurs (signaling inspiratory effort) or at a time limit of 3 seconds. Utilizing the software of pulmonary function cart, a HBR is defined as being present if occlusion time is 125% > average expiratory time. Paralyzed patients were studied during a 10-s period of CPAP. Adequate relaxation was defined as present if no respiratory effort was noted. 15 patients were studied during 25 separate testing periods.

Age	Sedated	Paralyzed	None	Total
< 1 mo	3/4	1/1	0/0	4/5
1-6 mos	2/2	3/3	0/1	5/6
> 6 mos	2/6	5/5	0/3	7/14

A positive test is one in which adequate chest-wall relaxation is demonstrated. Results are shown as positive tests/total tests. We conclude that OT is valid for study of passive respiratory system mechanics in non-neonatal patients, if adequate chest-wall relaxation can be achieved. In sedated patients, testing for presence of HBR identified patients in whom successful measurement of passive mechanics could be obtained. No child > 6 months of age could be tested with OT unless sedated and/or sedated and paralyzed. (OF-92-196)

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Topics in Pediatrics

Preliminary Findings: The Appropriateness of Bronchodilators in Pediatrics—John W Salyer RRT, Joanna M Lynch RRT, Madolin K Witte MD. Primary Children's Medical Center, *Salt Lake City, Utah.*

Introduction: We tested the assumption that some aerosolized bronchodilator therapy (ABD) given to our pediatric patients is either not indicated (inappropriate) or has no appreciable effect on the patient (ineffective). **Methods:** Respiratory care practitioners (mean tertiary pediatric respiratory care experience 8.2 y) were trained to assess the appropriateness and effectiveness of ABD using a protocol and form designed for the study. Findings were not posted in patient charts or used to modify care—to avoid having desire to reduce work loads compromise the assessor's objectivity. Patients were enrolled if they (1) had orders for ABD, (2) did not have chronic lung disease or cystic fibrosis, and (3) were receiving non-critical care. Indications were (1) wheezing, (2) dyspnea, and (3) tachypnea. Effectiveness was defined as any improvement in any of these findings after treatment. Patients were categorized as (1) emergency department (birth to 18 y), (2) in-patients < 1 y of age (infant unit), and (3) in-patients > 1 < 18 y (school age/toddler units). This study was not designed to identify patients who may have needed therapy but had none ordered. **Results:** 246 patients were assessed; emergency department = 26, school age/toddler unit = 129, infant unit = 91. ABD was found to be not indicated in 20% (emergency department = 8%, school age/toddler = 16%, infant unit = 30%). ABD was found ineffective in 11% of patients (emergency department = 4%, school age/toddler unit = 9%, infant unit = 15%). **Discussion:** As much as 31% of ABD in this population in our facility may be either inappropriate or ineffective (45% of patients < 1 y old). This may be attributable to the difficulty in assessing the effectiveness of such therapy in very young patients. Some of the therapy that was deemed ineffective might have been changed to a more efficacious intervention, but we did not seek to change ordered therapy. Among the confounding variables are lack of objective measures of effectiveness of ABD in pediatrics. If these findings are partially a result of inability to identify BD efficacy, it highlights the need for more refined assessment tools for clinicians to use at the bedside of infants and children. Findings also point out the need for consensus between medical and respiratory staff about what constitutes an indication for ABD. In 1991 we gave 51,081 ABD. Thus, we may have given as many as 10,216 (20%) that were unnecessary (deemed inappropriate), potentially developing $164,478 in charges to patients, families, and society and incurring as much as $105,633 in personnel expenses to give therapy that probably was of no benefit to the patient. **Conclusions:** Findings demonstrate need for (1) improved education of medical, nursing, and respiratory staff regarding indications for ABD, and (2) an on-going process for evaluating, documenting, and reporting to medical staff the appropriateness of ABD. We are implementing such a program and assessing whether it has an effect on reducing the amount of inappropriate and ineffective ABD. (OF-92-007)

School-Based Peak Flow Monitoring for the Child with Asthma—Gretchen E Lawrence BA RRT, Mark W Millard MD. Baylor University Medical Center, *Dallas, Texas.*

Asthma is known to be a leading cause for school absenteeism. Our center designed a school-based peak flowmeter (PFM) program for a large urban school district that had identified more than 2,700 asthmatic students who reported symptoms during regular school hours in the 1990-91 school year. The purpose of the program was to teach the correct monitoring of peak flow (PF) and guide school personnel in making safe and appropriate medical decisions for the asthmatic child. Three groups of 40 nurses each attended a 1-hour educational session. Materials provided were (1) PFM with instructions, (2) graph to record sequential PF symptoms, (3) nomogram for predicting PF, and (4) decision tree to provide guidance in determining appropriate action to take when the child's PF was decreased. Emphasis was placed on review of the step-by-step process of calculating PF, recording appropriate information, and using the decision tree. Caution was advised in doing repeated PFs in the child with obvious severe symptoms, as the maneuver itself could increase bronchospasm. We suggested that PFs be recorded when the child was symptom-free, so that when symptoms presented, their severity could be more accurately evaluated. A follow-up survey done 3 mo after program implementation revealed that 66% of the school nurses used the PFM from 1-5 times per wk; 62% said the device allowed for more timely medical intervention; 53% felt that use of the PFM improved both student compliance with medications and nurses' and other school personnel understanding of asthma. We concluded that PF monitoring at school is useful to both assess symptoms and to increase awareness of the impact of asthma on the school-age child. (OF-92-054)

Metered Dose Inhalers (MDIs) in Pediatrics: A National Survey—Robert M Lewis BA RRT. The Children's Memorial Hospital, *Chicago, Illinois.*

The use of MDIs is advocated as a cost-containment measure. Most reports of successful use of MDIs are from adult hospitals. Little is known about extent of MDI use in pediatric inpatients and emergency room (ER) patients. Therefore, I conducted a survey of children's hospitals (CHs) and general university-affiliated hospitals (GHs). **Method:** 56 CHs and 44 GHs were sent a survey to determine (1) the extent of MDI and conventional nebulizer (CN) usage, (2) circumstances under which MDIs are or are not used, and (3) factors associated with high MDI use in pediatrics. **Results:** 55 hospitals (33 CHs, 22 GHs) responded. 32 (57%) used MDIs in pediatrics. In these hospitals, only 10% (median) of all aerosol treatments (txs) were given by MDI (range < 1 to 74%). GHs gave a larger percentage of pediatric txs by MDI (median 25%) than CHs (6%) ($p < 0.05$, Wilcoxon rank sum test). GHs were also more likely to allow respiratory therapists to automatically switch from CN to MDI (58% vs 17%, $p < 0.05$, χ^2 test). Among 32 hospitals offering MDIs to pediatric patients, MDI use was highest in ventilated patients: 37% indicated that MDIs were

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used "frequently" or "almost always" on pediatric or neonatal ventilator patients. MDIs were least accepted in ER: 58% did not use MDIs in ER; of remaining, only 16% did a substantial portion (> 40%) of treatments as MDIs. 19 hospitals provided sufficient information to calculate overall tx (MDI and nebs) rate/bed. Median tx rate was 393 tx/bed/yr (range 32-651). **Conclusion:** Rate of MDI use is low in pediatrics. MDI use appears best accepted in ventilated patients and least accepted in ER. Pediatric patients in GHs are more likely to receive MDIs than those in CHs, and therapists are more often allowed to automatically switch to MDI therapy in GHs than in CHs. (OF-92-062)

ETT Pressure Necrosis in a Pediatric Cardiac Intensive Care Unit (CICU)—Patrice K Benjamin RRT, John E Thompson RRT, John H Arnold MD. Children's Hospital, *Boston, Massachusetts.*

One complication associated with intubation is pressure necrosis (PN) from the endotracheal tube (ETT). We prospectively studied occurrence of PN in a pediatric CICU. **Methods:** For a 6-wk period, all intubated, mechanically ventilated CICU patients were enrolled in the study. Upon study admission, the RT recorded demographics and route of intubation. Each shift (until extubation), each patient was assigned an appearance score (AS), which described the tissue adjacent to the ETT: 1 = normal, 2 = red—skin intact, 3 = red—outer skin layer broken, 4 = ulcerated, 5 = ulcerated—skin oozing, and 6 = necrotic. Frequency of retaping was noted. Data were then analyzed for incidence of PN, correlation between PN and duration of intubation (DOI) and retaping frequency, and oral-nasal differences. **Results:** 129 patients, ages NB to 24 y, were studied. DOI was 1-12 d [mean (SD) 3 (3)]. With single highest AS reported: 1 was noted in 78% (100), 2 in 18% (23), 3 in 3% (4), 4 in 2% (2), 5 and 6 in 0. Problematic PN (AS > 2) was 5.6 (6) %. DOI significantly correlated with AS ($p < 0.001$); retaping frequency was not independently correlated with AS when DOI was included in regression. PN was not correlated with patient age. Although PN occurred in 6% of nasally intubated patients and in 0 orally intubated patients, the difference did not reach statistical significance. All nasal PN occurred in patients with a DOI ≥ 5 d (sensitivity 1.0, specificity 0.83, positive predictive value 0.22, negative predictive value 1.0). **Discussion:** PN is a potentially disfiguring complication of prolonged intubation. Our data suggest that DOI < 5 days may not be associated with PN and that retaping frequency, which may be associated with improved skin care, did not influence frequency of PN. We believe that careful observation for PN should be a component of routine care for all intubated patients and that patients with DOI > 5 d should be assessed even more closely. (OF-92-113)

Response Time in Two Brands of Pediatric Ventilators—John W Salyer RRT, Joanna M Lynch RRT, Otwell Timmons MD, Connie Watkins RRT, Jim Keenan RRT. Primary Children's Medical Center, *Salt Lake City, Utah.*

Introduction: We sought to determine response times of Bird VIP (Bird Products) & Servo 900C ventilators (Siemens-Elema). **Methods**: 5 of each model of ventilator were tested. Response time (Tr) was determined by method similar to one described by Epstein (Anesthesiology 1971;34:321-326), and later modified by Martin et al (Anesthesiology 1989;71:977-981), in which ventilators were each attached to pediatric ventilator circuit and circuit-Y connector was occluded. Pressure was monitored with transducer at Y connection and printed on strip-chart recorder. A syringe was attached to 3-way stopcock inserted into circuit at Y. A 5-mL partial vacuum was generated in syringe by pulling plunger back and was then instantaneously introduced into the ventilator circuit by opening the stopcock. Tr was defined as elapsed time from initiation of negative airway pressure to attainment of 1 cm H_2O positive pressure during ventilator response. Three test conditions were (1) CPAP = 0, PSV = 0; (2) CPAP = 5, PSV = 0; (3) CPAP = 5, PSV = 5. Measurements were repeated 5 times on each device at all 3 conditions. VIPs were tested in SIMV/CPAP mode with rate 0, while Servos were in CPAP or pressure-support mode. Sensitivity on devices was set at –1 cm H_2O for all conditions except the Servos during Condition 3, when it was necessary to decrease sensitivity to ≈ –6 cm H_2O to avoid autocycling. Differences between Birds and Servos at each condition and overall were tested for significance using Student's *t* test with significance set at < 0.05 & adjusted to < 0.0125 using Bonferroni correction for multiple comparisons. Differences between variances were tested with F-test with significance < 0.05. **Results**: Response times of all ventilators are expressed in milliseconds as mean (SD).

	Birds					
	#1	#2	#3	#4	#5	All Birds
Condition 1	56	76	60	60	65	63
	(5.5)	(9.6)	(3.5)	(3.5)	(5.0)	(6.1)
Condition 2	59	63	66	54	56	60
	(5.5)	(9.6)	(3.5)	(3.5)	(5.0)	(6.1)
Condition 3	62	57	53	52	57	56.2
	(9.1)	(5.7)	(7.6)	(2.7)	(2.7)	(6.7)
All Conditions						59.6
						(7.5)

*Denotes statistical significance.

	Servos						
	#1	#2	#3	#4	#5	All Servo	p Value
Condition 1	56	79	84	86	56	72	0.0015*
	(2.2)	(2.2)	(4.2.)	(4.2)	(4.2)	(14.1)	< 0.05*
Condition 2	41	75	87	87	57	69.4	0.0176
	(8.2)	(5.0)	(8.4)	(8.4)	(4.6)	(19.4)	< 0.05*
Condition 3	62	55	69	69	53	62.6	0.0268
	(2.7)	(6.1)	(4.2)	(4.2)	(4.5)	(8.0)	> 0.05
All Conditions						67.8	0.0001*
						(15.0)	< 0.05*

*Denotes statistical significance.

Discussion: Statistically significant differences exist in response times between devices in Condition 1 & overall, with Bird VIP generally having shorter response time. However,

differences (< 10 ms) are probably not clinically important. There also appears to be more variation within Servos than within Birds in Conditions 1 & 2. This was not seen in Condition 3 & may be due to need to reduce the sensitivity of Servos to avoid autocycling. (OF-92-161)

Blastomycosis in the Neonate—James A Coffman BS RRT, Michelle Moss MD. Arkansas Children's Hospital, Little Rock, Arkansas.

Blastomycosis in the neonate is an extremely rare but old disease here revisited. Only 7 cases have been previously reported in the neonate (Pediatr Infect Dis 1987;1:76-77). Of these cases, 6 survived and 1 expired. On 12-23-91, an 18-day-old presented with a history of poor feeding, tachypnea (88), cough, respiratory distress, and subjective fever. Patient was placed in a 55% O_2 hood. ABGs were pH 7.35, P_{aCO_2} 36 torr, P_{aO_2} 75 torr. The x-ray showed patchy infiltrates bilaterally. Bacterial and viral cultures were taken, and ampicillin and cefotaxine were started. On 12-25, the patient's condition worsened, requiring intubation and mechanical ventilation. Cultures remained negative. On 12-27 with no improvement in respiratory status or chest x-ray, an open lung biopsy was done. It showed granuloma formation with sheets of broad-based budding yeast. Amphotericin B was started. On 12-29, progressive respiratory failure required increased ventilatory support with settings of SIMV 40, F_{IO_2} 0.65, V_T 50 mL, and PEEP 7 cm H_2O; hypoxemia became marked and patient was placed on extracorporeal membrane oxygenation (ECMO). 12-31 to 1-10 as renal function worsened, patient was placed on continuous arteriovenous hemofiltration with intermittent dialysis. 1-11 with worsening fungal sepsis and multiple organ failure, ECMO was discontinued and infant expired. The infant's mother had a purulent ulcer on her right leg just above the ankle that on x-ray showed extensive osteomyelitis. From this a clinical diagnosis of blastomycosis was made. The mother refused further testing and medical treatment. This case is presented in the hope that this diagnosis not be overlooked in the neonate who presents with a pneumonic process not responding to normal antibiotic therapy and to stimulate further investigation into how this disease, which normally affects adults or older children, is transmitted to the neonate. (OF-92-173)

Case Summary: Rescue Use of SensorMedics 3100A in an 18-Month-Old Child with Severe Air Leak and ARDS—Rodney L Blower RRT, Cathie Rea RN BSN RRT, Greg Redding MD. Children's Hospital and Medical Center, *Seattle, Washington.*

An 18-mo-old 12-kg boy was admitted to our Pediatric Intensive Care Unit with history of recent treatment for acute lymphoblastic leukemia. He presented with severe respiratory distress & required 100% O_2 via NRB mask. The patient was intubated & placed on a Servo 900C in pressure control mode. Patient's condition, CXR, & ABGs worsened over next 24 hours. Major problems on Day 2 of assisted ventilation were hypoxemia, bilateral pneumothoraces, pneumomediastinum, & severe subcutaneous air, with 3 chest tubes placed.

Servo Settings & Blood Gases

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1	1.0	5	20	40	10.8	7.41	28	37
4	1.0	10	50	40	23	7.45	26	58
46	1.0	12	50	46	27.8	7.42	33	52

After 46 h, patient was placed on SensorMedics 3100a Oscillator. Over initial 4 hours, both MAP & amplitude (AMP) were increased above MAP of 2 cm H_2O delivered by conventional ventilation. However, oxygenation improved immediately. By Day 2 of oscillation, CXR showed improvement in air leaks, fewer blebs, fewer infiltrates, & less subcutaneous air. By Day 6 of oscillation, MAP was decreased to 28 cm H_2O with continued improvement in oxygenation, suggesting improved alveolar patency & less air leak. However, coincidentally, ventilation became a problem with increased P_{aCO_2}. On Day 10, CXR had improved dramatically. 1 chest tube was in place with a small leak, & subcutaneous air had resolved. Paralysis was discontinued allowing spontaneous breathing. The child then appeared to mobilize unsuctioned secretions that obstructed his ETT. He required vigorous hand-ventilation with high pressures & repeated tracheal lavage & suctioning. This episode resulted in P_{aCO_2} 185, P_{aO_2} 72, pH 6.91. Patient was switched back to Servo 900C on settings of F_{IO_2} 1.0, PEEP 6, pressure control 32 cm H_2O, IMV 30, MAP 14.5, with pH 7.28, P_{aCO_2} 66, P_{aO_2} 70. CXR showed virtually no extrapulmonary air with few infiltrates. The patient remains on a P-B 2800 ventilator at low settings, with chronic lung disease but otherwise showing normal development.

	Oscillator Settings					Blood Gas Values		
Hour	F_{IO_2}	MAP	AMP	Hz	IT%	pH	P_{aCO_2}	P_{aO_2}
1	1.0	40	30	10	33%	7.09	83	64
6	1.0	44	58	7	40%	7.33	40	90
24	1.0	32	59	7	40%	7.35	39	87
48	1.0	32	59	7	40%	7.31	49	97
72	1.0	28	60	7	40%	7.44	47	91
Day 6	0.79	23	71	4	40%	7.35	79	79
Day 10	0.58	21	71	4	40%	7.49	48	84

Conclusion: Our experience suggests that use of HFOV be considered as an alternative for rescue of pediatric patients with pulmonary air leak/ARDS and decreasing P_{aO_2}s. (OF-92-178)

Validation of a Metabolic Monitor for Use during Pediatric Mechanical Ventilation—Frank Kilpatrick RRT, Samuel J Tilden MD, University of Alabama at Birmingham; Children's Hospital of Alabama; Calvin L Long, Alan S Waland, Baptist Medical Center—*Birmingham, Alabama.*

Although several validations of metabolic monitors have been reported for mechanical ventilation at adult ranges of tidal volumes (V_T) and inspiratory minute ventilation (V_I) few if any reports exist on the accuracy of such devices for pediatrics. We investigated one such monitor, Deltatrac (Datex Corp) under conditions of low V_I and V_T appropriate for pediatric ventilation. A lung model consisting of a Plexiglas box reservoir connected to a rubber test lung was ventilated with a Servo 900C ventilator at 20 breaths/min and variable V_T to give V_I of 0.6, 1.5, 3.0, and 6 L/min. Three different known flows of CO_2 and

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N_2 were introduced to simulate $\dot{V}_{CO_2}$ and $\dot{V}_{O_2}$. Prior to studies, metabolic monitor was calibrated by performing an ethanol burn (5 mL) and measuring $\dot{V}_{O_2}$ and $\dot{V}_{CO_2}$ within 2%. For each ventilator setting & flowrate, 10-min averages were recorded after a 20-min wash-in period to achieve steady state. Data suggest that accurate CO_2 and $\dot{V}_{CO_2}$ can be obtained in mechanically ventilated pediatric patients requiring low V_I. Results for $F_{IO_2} = 0.21$ are shown.

Measured vs Predicted $\dot{V}_{CO_2}$ & $\dot{V}_{O_2}$ at Varying V_T

$\dot{V}_{CO_2}$ (mL/min)	V_I (L/min)			
	0.6	1.5	3.0	6.0
64	65 (2)*	66 (3)	65 (2)	—
115	—	114 (1)	116 (1)	113 (2)
226	—	—	221 (2)	220 (3)

$\dot{V}_{O_2}$ (mL/mi)	V_I (L/min)			
	0.6	1.5	3.0	6.0
170	72 (3)	71 (1)	70 (6)	—
154	—	157 (2)	154 (0)	151 (2)
248	—	—	253 (2)	249 (0)

*Values in parentheses are percent change from predicted.

(OF-92-197)

Neonatal and Infant Ventilation and ECMO

Surfactant Administration by Infusion Pump—Kaye R Weber BA RRT, John B Paton MD, Sherry E Courtney MS MD. Humana Hospital-Michael Reese and University of Illinois, *Chicago, Illinois.*

During the clinical trials of Exosurf, a synthetic surfactant, we noted that many infants at our institution experienced at least one episode of low oxygen saturation by pulse oximeter (S_{pO_2}) during dosing. We hypothesized that a method of slow, continuous infusion of drug would improve patient tolerance as evidenced by the number of infants who had at least one episode of low S_{pO_2} (< 85%). We randomized 24 infants for whom Exosurf had been prescribed, to receive the drug by the traditional hand method (n = 11) or infusion pump (n = 13). Each half-dose was administered over approximately 10 min by both methods. We recorded transcutaneous P_{CO_2} (P_{tcCO_2}), S_{pO_2}, and ECG continuously during the dose. Continuous variables were compared with independent *t* tests and dichotomous variables with Fisher's Exact χ^2 on proportions. **Baseline characteristics:**

Variable	Pump	Hand
Birthweight (g)	1172 (383)*	967 (284)
Gestational age (wk)	29 (2)	29 (2)
Sex (male)	9/13	3/11†
Age at dose (h)	15 (19)	7 (6)
P_{aO_2}/P_{AO_2}	0.16 (0.06)	0.30 (0.18)†

*Values are mean (SD).
†$p < 0.05$.

Results:

	First Half-Dose		Second Half-Dose	
Infant condition	Pump	Hand	Pump	Hand
$S_{pO_2} < 85\%$	1/13	2/11	4/13	1/11
$P_{tcCO_2} > 5$ torr	3/13	2/11	2/13	1/11

None of the differences in outcome measures is significant at the 5% level. No infant experienced bradycardia (< 100 bpm) or tachycardia (> 180 bpm) during dosing. We conclude that administration of Exosurf by infusion pump is a safe alternative to hand injection. Patient tolerance is likely more dependent on the duration of the dose than on the method of administration. (OF-92-037)

Inspired Tidal Volume (V_T) Measurements during High Frequency Oscillatory Ventilation (HFOV)—Frank Monaco BA RRT, Keith S Meredith MD, Ted Tabor CBET RRT. Memorial Hospital, *Colorado Springs, Colorado,* and Med-Science, *St Louis, Missouri.*

Introduction: We bench tested a data acquisition system (DAS) (CODAS, Dataq Instruments), sampling frequency 1,000 Hz, to measure inspired V_T during HFOV (3100A SensorMedics) and compared these data to a commercially available monitoring system (VenT, VenTrak, Med-Science), sampling frequency 100 Hz. **Methods:** The flow signal (voltage) from a hot wire anemometer (NVM 1, Bear Medical) was used for each system. The accuracy of the AS was verified by injecting 2 to 100 mL from calibrated syringes. The mean difference ranged from mean (SD) 3.10 (0.2) mL at 100 mL to –0.3 (0.01 mL) at 2 mL. Anemometer frequency response was tested by measuring volumes (AS) generated by a single-stage diaphragm micropump, stroke volume = 0.75 mL at frequencies from 10 to 60 Hz. Mean (SD) difference ranged from 0.06 (0.003) mL at 10 Hz to –0.06 (0.002) mL at 60 Hz. The anemometer was placed between the HFOV and a 3.5-mm ETT that was connected to a neonatal test lung, $C_L = 0.001$ L/cm H_2O. HFOV settings: $\bar{P}_{aw} = 10$ and 20 cm H_2O, f = 10 and 15 Hz and oscillatory amplitude (OA) = 10 to 40 cm H_2O. I:E = 1:2, flowrate = 15 L/min. **Results**: DAS V_T were higher than VenT [pooled mean (SD) AS V_T = 7.1 (2.5) mL vs VenT = 2.3 (1.2) mL]. Both methods showed expected trends as V_T varied directly with OA, inversely with rate, and $\bar{P}_{aw}$ had no effect. **Conclusion**: (1) The NVM 1 provided accurate flow signals from 10-60 Hz, (2) the precise HFOV V_T can be calculated from this flow signal (table), and (3) the differences in results between the two systems may be the result of sampling frequency. (ΔP = pressure change) (OF-92-055)

DAS Tidal Volumes (in mL; mean, SD)

ΔP	$\bar{P}_{aw}$ 10 10 Hz	$\bar{P}_{aw}$ 20 10 Hz	$\bar{P}_{aw}$ 20 15 Hz	$\bar{P}_{aw}$ 10 15 Hz
10	4.6 (0.004)	4.5 (0.010)	3.1 (0.007)	2.9 (0.023)
20	7.8 (0.017)	7.4 (0.017)	5.4 (0.021)	5.0 (0.028)
30	9.7 (0.013)	9.6 (0.011)	6.9 (0.024)	6.6 (0.024)
40	11.5 (0.006)	10.6 (0.004)	8.1 (0.018)	8.1 (0.015)

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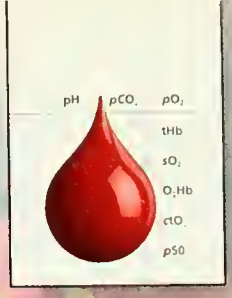

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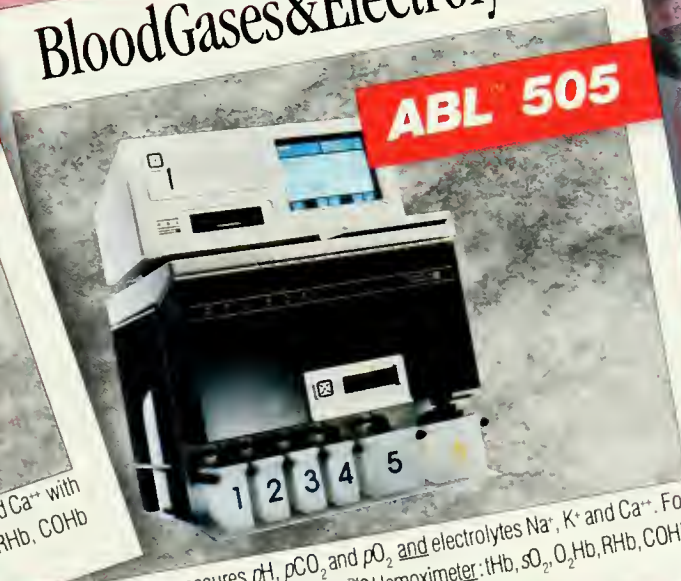

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Lung-Volume-Dependent Effects of Changing Inspiratory Time during High-Frequency Oscillation—Kaye R Weber BA RRT, Sherry E Courtney MS MD, Kevin Karcz, Paul S Levy ScD. University of Illinois and Humana-Michael Reese, *Chicago, Illinois.*

Studies to define the device and disease-specific strategies for use of high frequency oscillation (HFO) on sick neonates are urgently needed. The SensorMedics 3100 oscillator provides for variation in inspiratory time (IT), but no evidence exists for the utility of this option. We studied 12 New Zealand White rabbits after saline lung lavage to determine the IT effects that are dependent on lung volume (LV). High LV (HLV) and low LV (LLV) are defined as baseline LV (BLV) ± 33%. Animals were randomized to HLV or LLV and placed in a body plethysmograph. IT was varied randomly, and data were taken at BLV and at either HLV or LLV for each IT. We tested the hypothesis that there are no LV-dependent effects of changing IT on a/A, cardiac output (C.O.), P_{CO_2}, and V_T for each IT under each LV. Cardiac output and V_T are indexed to body weight. We performed analysis of variance for repeated measures and report the p values for the primary response variables below.

	IT & LV*	HLV vs LLV†	IT‡	BLV vs HLV/LLV (interaction)¶
a/AO2	0.640	0.006	0.796	0.002
V_T	0.353	0.939	< 0.001	0.636
C O./kg	0.129	0.04	0.173	< 0.001
P_{CO_2}	0.939	0.379	< 0.001	0.006

*Body weight, number of lavages required, LV change and a/A prior to protocol were not different between LV groups. Under protocol, no effect of IT was dependent on LV.

†a/AO2 was significantly increased and C.O. was reduced with HLV.

‡The effect of IT for V_T and P_{CO_2} was significant.

¶The interaction of BLV vs either LLV or HLV was significant for all variables except V_T.

We conclude that the effects of changing IT are independent of changes in LV. The response of P_{CO_2} to IT is likely related to V_T. However, because increasing IT may increase LV, one must balance the risk of lung overdistention with possible clinical advantage for the difficult-to-ventilate infant. (OF-92-076)

Feasibility and Effectiveness of Staffing an NICU with Advanced Practitioners—David M Barton PhD RRT. University of Virginia Health Science Center, *Charlottesville, Virginia.*

Introduction: This study was conducted to determine the feasibility and perceived effectiveness of replacing OJT and entry-level RCP staff in an NICU with advanced practitioners (APs). Research questions pertained to the perceptions of nurses and physicians' (MDs) about the scope and level of respiratory practice maintained and expected in an NICU. Specific research questions: (1) Does scope and level of practice (SLP) maintained by OJTs and entry-level RCPs in the NICU differ significantly from SLP expected when APs staff the NICU? (2) After 6 months of staffing with APs, is SLP maintained significantly > that maintained by OJTs and entry-level RCPs? (3) Is SLP maintained by APs significantly different from pre-AP staffing SLP expected? (4) Is SLP expected after staffing with APs significantly different from SLP expected before staffing with APs? (5) Is SLP expected after staffing with APs significantly different from SLP maintained by APs? **Method:** A 2-subscale survey based on the AARC Task Inventory for Advanced Practitioners was administered to NICU nurses and MDs before AP staffing and 6 months after AP staffing. Respondents rated 14 task-inventory items according to how frequently they perceived the tasks' being *currently* performed (maintained SLP) and how frequently they perceived the tasks *should be* performed (expected SLP). A 6-point item-response scale ranging from 1-NEVER to 6-ALWAYS was used. Subscale inter-item reliability was assessed using Cronbach's coefficient alpha. Mean SLP subscale scores were compared using dependent *t* tests with a priori significance set at 0.05. **Results:** Coefficient alpha for all subscales compared was > 0.9600. Nurses and MDs' mean SLP scores did not differ significantly; therefore, their results were pooled. The mean score for the SLP maintained by OJTs and entry-level RCPs was significantly < mean score for the expected SLP if APs were to staff the unit (3.47 vs 4.92). 6 months after staffing with APs, mean score for the SLP maintained was not significantly different from prestaffing mean score for expected SLP (4.71 vs 4.92). Mean score for SLP maintained by APs was significantly > mean score for SLP maintained by OJT/entry-level RCP staff (4.71 vs 3.47). Mean score for expected SLP increased significantly after 6 months of staffing with APs (4.92 vs 5.26). Mean score for SLP maintained by APs was significantly < mean poststaffing score for expected SLP (4.71 vs 5.26). **Conclusions:** (1) Nurses and MDs perceived a need for advanced-level respiratory care practice in the NICU. (2) APs were perceived as maintaining a significantly higher level of respiratory care practice than OJTs and entry-level RCPs. (3) APs met prestaffing expectations of scope and level of respiratory care practice in an NICU. (4) Nurses and MDs' expectations of scope and level of respiratory care practice increased, thought not significantly, after 6 months staffing with APs. (5) APs in the NICU can continue to increase scope and level of respiratory care practice. (OF-92-085)

Neonatal Veno-Venous ECMO: Are There Contraindications?—Lynne K Bower RRT, Jay M Wilson MD, Patrice K Benjamin RRT, James Fackler MD. Children's Hospital, *Boston, Massachusetts.*

Introduction: The Kendall double-lumen cannula (DLC) has revitalized the application of veno-venous (V-V) ECMO in the neonate. V-V ECMO has potential advantages over venoarterial (VA) ECMO—specifically, the avoidance of carotid artery interruption, full pulsatile flow, and the perfusion of oxygenated blood through the pulmonary vascular bed and coronary arteries. However, lack of cardiovascular support may limit its application. To date the principal contraindication for

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the DLC has been hemodynamic instability. We analyzed our experience with the DLC to define which pre-ECMO variables were associated with conversion to VA support. **Methods:** 30 neonates were cannulated with the DLC from 4/91 through 4/92. Their diagnoses were 16 meconium aspiration/persistent pulmonary hypertension (MAS/PPHN), 9 sepsis, 4 congenital diaphragmatic hernia (CDH), and 1 cardiac postoperative patient. Concurrently, an additional 29 neonates received VA support due to either a small right internal jugular vein, CPR, or unfamiliarity of the staff with the DLC. The patients were separated into two groups, the nonconverted DLC (NC) and the converted group. **Results:** 6/30 neonates were converted to VA ECMO due to cardiovascular instability, 1/16 (6%) MAS, 4/9 (44%) sepsis, and 1/4 (25%) CDH. There was no significant difference between the two groups prior to ECMO, based on weight (range 2.5-4.3 kg), oxygen index (OI) (range 030-0.86), and mean BP (range 35-80 torr). Requirements for dopamine (2.5-25 μg/h) and dobutamine (5-25 μg/h) were also not significantly different for the 2 groups. However, 4/6 (66%) converted patients had the additional requirement of epinephrine compared to 1/24 in the NC group. **Discussion:** Based on our experience with the DLC, we conclude that (1) no neonatal diagnosis is a contraindication to V-V ECMO, (2) pre-ECMO OI or mean BP is not a predictor of failure, (3) even high levels of dopamine and dobutamine do not disqualify candidates, and (4) only a requirement for epinephrine in addition to the other inotropes appears to be associated with failure of DLC support. (OF-92-095)

Comparison of Spontaneous Inspiratory Work with Three Types of Infant Ventilator Flow Options—Kelvin MacDonald RCP CRTT, Cyndy Miller RCP RRT, Peter Wong RCP, Kaiser Permanente Medical Center-LA, *Los Angeles, California.*

Previously, ventilators used to mechanically ventilate infants provided a single continuous-flow adjustment. The flowrate chosen to achieve the desired pressure waveform-rise time for mechanical breaths was also the flow that the patient breathed from in between mechanical breaths. Two recent ventilators incorporate alternate flow systems. One has a demand-flow system for spontaneous breathing with a preset continuous background flow of 4 L/min. The other features a demand-flow system for spontaneous breathing with an adjustable continuous background flow. We studied 3 different ventilators using the 3 different flow delivery systems to determine whether patient spontaneous inspiratory work at the airway is affected by the type of spontaneous flow delivery system. **Methods:** A rotary piston pump was used with a double infant drive/slaved lung arrangement (Michigan Instruments, TTL) with a system compliance of 0.01 L/cm H_2O. The rotary pump was adjusted to 'spontaneously breathe' at 60 bpm, V_T 6 mL, flow 3 L/min on the drive lung. Each ventilator, set to deliver IMV 10 bpm, PIP 15 cm H_2O, PEEP + 3 cm H_2O, mechanical flow 12 L/min, was then in turn connected to the slave lung via standard 128-cm pediatric ventilator circuit (ID 12 mm) and 3.5-mm ID ETT. A Med-Science VenTrak Respiratory Monitor incorporating a hot-wire anemometer (NVM, Bear Medical, Riverside CA) and pressure-sensing line was employed between the patient circuit and slave test lung to record pressure, flow, and volume. The Bear Cub Ventilator (Bear Medical, Riverside CA) was tested using continuous flow (CF) IMV. The InfantStar (Infrasonics, San Diego CA) was tested twice, once with continuous flow with IMV and once with demand flow (DF) with IMV. The Newport Wave Ventilator (Newport Medical Instruments, Newport Beach CA) was tested using bias flow (BF) plus demand flow with IMV. **Results:**

	Work (SD)*		
Cub	Star CF	Star DF	Wave BF + DF
3 (< 1)	3 (< 1)	2 (< 1)	< 1 (< 1)

*Mean (SD) work in g x cm.

Conclusion: The highest patient inspiratory work for spontaneous breathing in between mechanical breaths was found with the single-control, continuous-flow IMV on the Cub and InfantStar. Patient inspiratory work was reduced during spontaneous demand-flow breathing on the InfantStar. The lowest patient inspiratory work for spontaneous breathing in between IMV breaths was provided by the Wave Ventilator with bias flow plus demand flow. We conclude that patient spontaneous inspiratory work may be reduced by utilizing a ventilator that allows independent adjustment of mechanical and spontaneous flows. (OF-92-109)

ECMO Intervention in Central Hypoventilation Syndrome Complicated by ARDS—Mike Anders RRT, Mark J Heulitt MD, Ken Ewing RPFT RRT, Arkansas Children's Hospital, *Little Rock, Arkansas.*

Central hypoventilation syndrome (CHS), a rare congenital disorder, necessitates bilateral diaphragmatic pacing and some degree of mechanical ventilator dependence in children to obtain adequate ventilation. ARDS in the CHS child could result in total commitment to mechanical ventilation secondary to residual pulmonary damage. We report a 7-year-old CHS patient with a baseline status of 12 h of nighttime mechanical ventilation and 12 h of diaphragmatic pacing. The patient was mainstreamed in school and participated in physical activities such as tap dancing. The patient's initial presentation in the clinic consisted of a 4-day history of fever, increased secretions, increased F_{IO_2} requirements, and clear chest radiograph. 36 h after initial presentation, the patient was admitted to the ICU because of decreased P_{aCO_2}/F_{IO_2}, CO_2 retention, and bilateral alveolar infiltrates on radiograph. Over the next 48 h, patient required increasing levels of PIP and PEEP to maintain adequate oxygenation. Intervention with ECMO support was chosen in an effort to spare the lungs of potentially toxic F_{IO_2} and increased levels of peak inspiratory pressure (PIP). At this time, the patient's ventilatory support consisted of pressure control (PC) of PIP/PEEP 63/20 cm H_2O and F_{IO_2} of 0.65. On these settings the patient's ABG was pH 7.30, P_{aCO_2} 51 torr, P_{aO_2} 83 torr. PEEP-compensated PCWP was 16 torr with a

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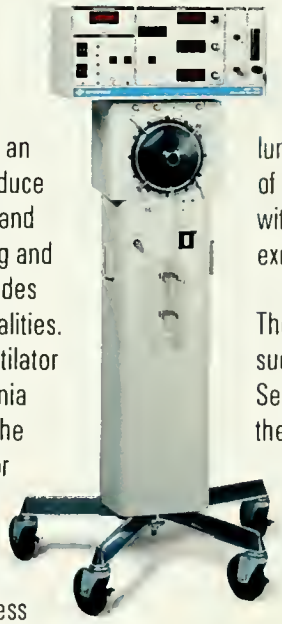

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mean PA pressure of 45 torr. The patient was placed on veno-arterial ECMO with flowrates of up to 2.0 L/min (87 mL/kg) to achieve adequate oxygen delivery, and reduce ventilator settings to PIP/PEEP 35/12 cm H_2O and F_{IO_2} 0.3 in the PC mode. On ECMO Day 8, a trial off ECMO was unsuccessful due to high PIP level and F_{IO_2} to maintain adequate oxygenation. On ECMO Day 12, the patient was successfully weaned from ECMO support, with full repair of both the internal jugular vein and carotid artery.

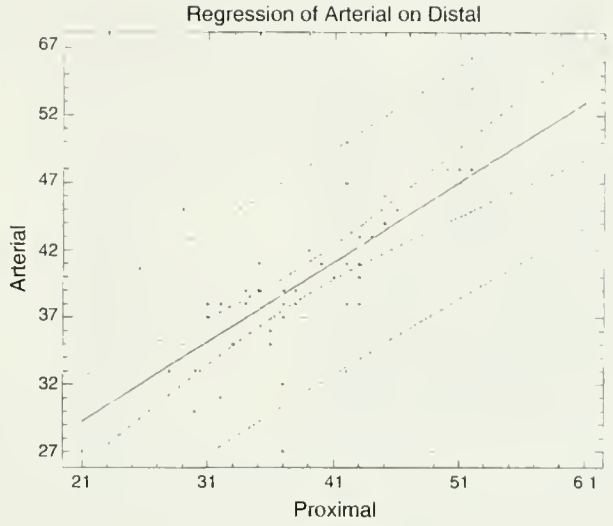
Selected Mean Pulmonary Compliance (mL/cm H_2O/kg)

ECMO Day 1	ECMO Day 2	ECMO Day 7	ECMO Day 8	ECMO Day 9	ECMO Day 12
0.07	0.16	0.17	0.28	0.25	0.37

The patient subsequently has been seen in follow-up clinic. Doppler flow studies of internal jugular vein and common carotid artery have been normal. The patient has returned to the baseline of divided time between diaphragmatic pacing and mechanical ventilation. ECMO intervention in rare occurrence of severe ARDS in a CHS patient provides a potential means of preserving baseline status in these children. (OF-92-136)

End-Tidal CO_2 Measurements in Intubated Neonates Weighing < 2000 Grams—Bryan Beatty CPFT RRT, Kosair Children's Hospital; John Roberts MD, University of Louisville School of Medicine—*Louisville, Kentucky.*

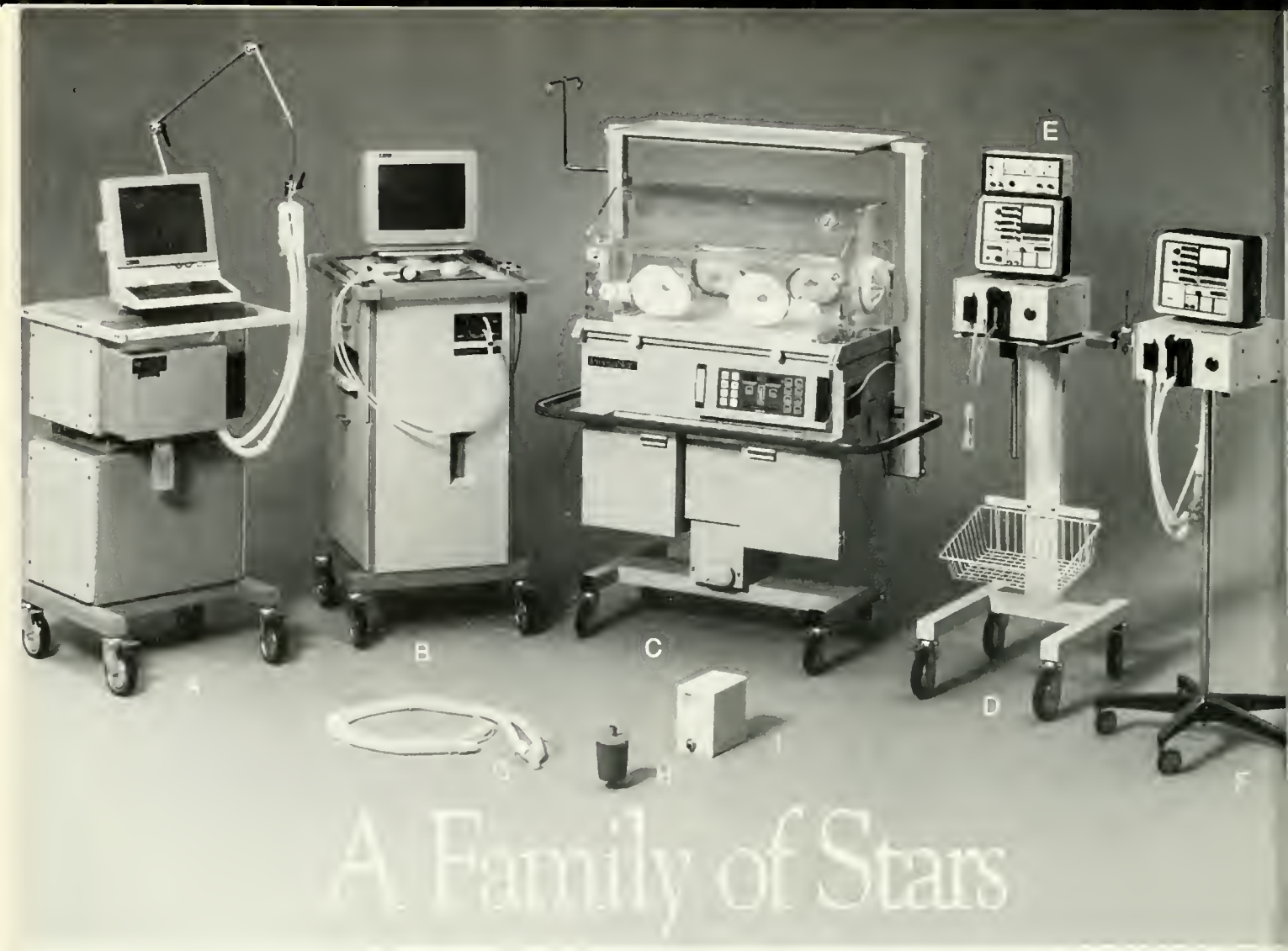
Newborn infants who require mechanical ventilation need frequent arterial blood gas (ABG) determinations to monitor their pulmonary course. Although pulse oximetry can provide reliable noninvasive monitoring of oxygen saturation, noninvasive monitoring of CO_2 is more problematic. P_{tcCO_2} monitors can cause burns, especially in small premature neonates. P_{etCO_2} monitors placed in conventional monitoring site (distal airway connection from ETT to ventilator) increase dead space and provide little correlation to ABGs. We speculated that measuring P_{etCO_2} at a more proximal site (proximal tip of a double-lumen ETT, DL-ETT), bypassing a substantial portion of dead space, would provide more reliable CO_2 measurement. **Methods:** Newborns weighing < 2,000 g who required mechanical ventilation and were intubated with a DL-ETT were studied. ABG samples via indwelling umbilical or radial artery catheters were collected with simultaneous sampling of end-expiratory gas at proximal (PROX) and distal (DIST) DL-ETT sites. 5 sample sets were collected from 30 min to 2 h apart over a period of 72 h, from each subject. Other monitored variables included IMV rate, PIP, PEEP, and spontaneous respiratory rate (SRR). Data were analyzed using linear regression for comparison of PROX vs ABG and DIST vs ABG CO_2 values. Analysis of variance was used to identify factors responsible for variances between PROX, DIST, and ABG samples. **Results:** 50 sample sets were collected from 10 low birthweight infants (range 0.67-1.95 kg), ABG CO_2 values ranged from 27-50 torr (SD 39). There was a linear relationship between DL-ETT PROX and ABG samples (P_{aCO_2} – 1.68 + 0.59 x PROX $etCO_2$, $r = 0.69$, $p < 0.01$), with no such



correlation between DL-ETT DIST and ABG samples ($p > 0.23$). Ability of a normal PROX CO_2 to predict a normal arterial CO_2 is 80%, an abnormal PROX CO_2 predicts an abnormal arterial CO_2 in 60%. ANOVA showed variability in DL-ETT PROX vs ABG and had no significant relationship to IMV rate, PIP, PEEP, or SRR. **Experience:** End-tidal CO_2 monitoring via a DL-ETT has been limited to research. However, use of equipment has been ongoing for 3 years. **Conclusions:** Statistical analysis of information gathered in this project reveals a high correlation between PROX and ABG samples and little correlation between DIST and ABG samples. Further research may show that PROX site sampling provides a reliable means of noninvasive CO_2 measurements, reducing need for blood gas samples and thus reducing need of blood transfusions in this patient population. (OF-92-148)

Resistance of a Series of Vital Signs Neonatal Hygroscopic Condenser Humidifiers—John W Salyer RRT, Roger Butler RRT. Primary Children's Medical Center, *Salt Lake City, Utah.*

Introduction: We sought to measure resistance (R, cm H_2O/L/s) & mechanical dead space of hygroscopic condenser humidifiers (HCHs) in an attempt to quantify magnitude of R & degree to which it varies in a series of HCHs, with view towards using such devices in a neonatal population. **Methods**: All pressure measurements were made with Timeter RT-200. R was determined at flowrates of 4, 8, and 10 L/min of air on 10 HCHs at each setting. Gas was conditioned with a wick-type heated humidifier. Heated wire was used in gas delivery tubing & temperature of gas as it entered HCH was maintained at 37°C ± 0.2°. Pressure readings across HCH were recorded immediately after attaching HCH (dry reading), & after 5 min of flow (wet reading). HCH dead-space volume of 25 devices was determined by removing hygroscopic filter, attaching HCH to ETT adapter, with plastic film inserted between them. Other end of the HCH was inserted into ventilator Y-adapter & sidewall of HCH was pierced along rim of Y. A syringe was



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then used to inject known volumes of water into HCH until it was filled from edge of ETT adapter to point corresponding to rim of Y. All values are reported as mean (SD). Differences were tested using a Student's 2-tailed *t* test with significance set at 0.05. **Results**:

Flowrate	R (Dry)	R (Wet)	p Value
4 L/min	3.06 (0.26)	3.14 (0.30)	0.016
8 L/min	4.17 (0.25)	4.35 (0.26)	< 0.001
10 L/min	4.28 (0.33)	4.49 (0.36)	< 0.001

Mechanical dead space (DS) was found to be 2.2 (0.13) mL. **Discussion**: While there appears to be a statistically significant difference between wet & dry readings for R at all flowrates, these differences do not appear to be clinically important. Degree of variation among devices appears to be acceptable, with regard to R. Flowrates represent those that might reasonably be expected to be encountered in neonates. Whether any of R values reported represent an important addition to patient's R_{aw} would seem to depend on magnitude of intrinsic R_{aw}. Because we are considering using these devices on neonates, one should consider that neonates with respiratory distress syndrome have been reported to have values of R ranging from 50-180 cm $H_2O \cdot s \cdot L^{-1}$. Use of these HCHs would probably constitute a 2-9% increase in R_{aw} in neonates. Whether DS of 2.2 mL constitutes a significant addition to DS would depend on ventilatory mode used. With continuous-flow modes, DS of this magnitude has generally not been shown clinically to have an effect on P_{aCO_2}. Ability of these devices to adequately condition inspired gas remains to be tested in neonates. **Speculation**: Use of these devices will probably not result in an important increase in R_{aw}. However, their efficacy with regards to humidification awaits testing in neonates. One interesting use of these relatively inexpensive devices might be to condition the gas during short-term ventilation with manual resuscitators. (OF-92-162)

Patient Inspiratory Work of Breathing (WOB) by a Neonatal Heat and Moisture Exchanger (HME)—Kelvin MacDonald RCP CRTT, Peter Wang RCP CRTT, Cyndy Miller RRT. Kaiser Permanente Medical Center-LA, *Los Angeles, California.*

At our facility, we use a HME during transport of intubated neonates rather than a conventional humidifier system. We are concerned about increased work during spontaneous breathing and, therefore, evaluated the neonatal HME (Vital Signs Inc) used in our NICU. Using varying flowrates consistent with spontaneous breathing, we determined patient inspiratory work through the HME. **Methods**: A rotary piston pump (variable rate and stroke) was set for tidal volume of 30 mL. A hot-wire anemometer (Bear Medical) and airway pressure line, interfaced to a Med-Science VenTrak Monitor was placed between the HME and the lung apparatus. Flowrate was calculated as Flow x I-time = V_T. Respiratory rate was then varied to produce flows 2 L/min, 4 L/min, and 6 L/min. Pressure and flow signals were collected for a 10-breath average for each flowrate with the HME on and off. We breathed through the HME for 5 min prior to each measurement to heat and humidify it. The data were stored and calculations made on an IBM-compatible PC. **Results**:

Flowrate in L/min	Mean Work in g · cm (SD)
2	0.5 (0.5)
4	4.7 (0.5)
6	9.2 (0.6)

WOB increased in a linear fashion [$y = 2.175x - 3.9$, $R^2 = 1$] from 2 to 6 L/min. WOB at each flow setting without the HME remained at zero. **Conclusions**: Imposed work of breathing increased as flowrate increased. However, the work imposed at normal neonatal flowrate of 2 L/min was not significant. Clinical users should evaluate their patient's spontaneous flowrate and patient's contribution to total minute volume. (OF-92-189)

Comparison of Inspiratory WOB between Flow-Triggering and Pressure-Triggering Demand-Flow CPAP Systems in Rabbits—Masaji Nishimura MD, Ikuto Yoshiya MD, Osaka University Medical School; Hideaki Imanaka MD, Osaka University Hospital; Chikara Tashiro MD, Osaka Medical Center & Research Institute for Maternal & Child Health—*Osaka, Japan.*

It has been reported that inspiratory WOB is smaller in flow-triggering (FT) CPAP systems than in pressure-triggering (PT) CPAP systems in adults. We carried out the following experiment in rabbits to determine whether that may be the case in infants. **Methods**: We compared esophageal pressure deflection in FT and conventional PT CPAP systems on 6 white rabbits. The animals were intubated with a 3-mm ID endotracheal tube (ETT). Esophageal pressure (P_{es}), airway pressure, and flow signal were monitored. Tidal volume was calculated by electrical integration of flow signal. At first, rabbits were breathing room air through ETT without other respiratory circuitry (control). After the completion of measurements, they were connected to the Puritan-Bennett 7200 through standard respiratory circuitry. The operating conditions were CPAP mode with 0 cm H_2O PSV, FT; base flow, 5 L/min; trigger flow, 1 L/min, PT; trigger sensitivity, –1 cm H_2O. **Results**:

	Negative Deflection of P_{es} (% of Control Value)	
	FT	PT
Mean (SD)	78.53 (6.88)*	97.10 (10.98)

* By 2-way ANOVA and Scheffe's test, $p < 0.01$.

Negative deflection of FT was significantly smaller than that of PT. **Conclusion**: In terms of inspiratory work of breathing, FT may be better than PT in delivering CPAP to infants. (OF-92-200)

Evaluation of Pressure Support Ventilation in Neonate and Infant Lung Model—Jun Takezawa MD, Yurii Konyukov MD, Toshimichi Takahashi MD, Naoto Kuwayama MD, Toshiro Hotta RRT, Toshio Fukuoka RRT, Yasuhiro Shimada MD. Nagoya University Hospital, *Nagoya, Japan.*

We have evaluated efficacy of PSV applied to neonate or infant lung models. **Methods**: We used spring-loaded bellows-

type lung model. 2 bellows represented lung & diaphragm, & were placed in air-tight container. C_L & C_{cw} were 5 and 8 mL/cm H_2O, respectively. FRC was 150 mL. Diaphragm bellows was connected to time-cycled jet-flow generator to produce inspiratory efforts. Sizes of ETT were 2.5, 3.0, 3.5, and 4.0 mm. Spontaneous RR were 20, 40, and 60 breaths/min (I:E 1:1). A VIP Bird ventilator was used at pressure support (PS) levels of 0, 15, and 30 cm H_2O with a sensitivity of 2 cm H_2O. The side hole (1-mm ID) provided air leakage between distal end of ETT & lung bellows. Pressures were monitored at airway opening and alveolar and pleural spaces. Inspiratory trigger delay, cycling delay of expiration, auto-PEEP, and maximal PS level at which lung model could trigger ventilator were also determined. **Results**:

ETT 2.5-mm

RR (breaths/min)	20			40			60		
PS level (cm H_2O)	0	10	19	0	8	16	0	7	15
V_T (mL)	20	27	35	20	24	27	20	21	20
Inspir Delay (ms)	140	120	140	110	100	140	130	140	180
Expir Delay (ms)	70	90	240	90	80	240	120	120	320
auto-PEEP (torr)	0	0	0	0.5	0.9	1.6	7.1	8.9	11.6

ETT 3.0-mm

RR (breaths/min)	20			40			60		
PS level (cm H_2O)	0	10	20	0	7	14	0	6	13
V_T (mL)	20	34	45	20	25	30	20	24	21
Inspir Delay (ms)	100	120	130	100	110	120	100	110	160
Expir Delay (ms)	60	100	120	80	100	240	100	120	240
auto-PEEP (torr)	0	0	0	0.3	0.4	0.8	1.9	4.5	5.8

ETT 3.5-mm

RR (breaths/min)	20			40			60		
PS level (cm H_2O)	0	10	20	0	7	14	0	5	10
V_T (mL)	20	34	48	20	25	30	20	22	23
Inspir Delay (ms)	120	130	140	90	120	120	100	120	140
Expir Delay (ms)	70	90	200	90	100	280	100	100	180
auto-PEEP (torr)	0	0	0	0.3	0.4	0.5	1.3	2.2	2.3

ETT 4.0-mm

RR (breath/min)	20			40			60		
PS level (cm H_2O)	0	20	45	0	15	25	0	10	17
V_T (mL)	20	80	160	20	50	80	20	37	42
Inspir Delay (ms)	140	140	140	110	140	160	140	100	140
Expir Delay (ms)	60	90	140	100	100	200	70	140	160
auto-PEEP (torr)	0	0	0	0	0	0.4	0.4	0.6	3.1

Discussion: These data suggest that (1) significant triggering time delay is present in application of PSV to infants. (2) When small ETT is used, high PS level is not feasible because of difficulty in triggering. Phenomenon is aggravated at higher RR. (3) This may be due to expiration cycling delay contributing to development of auto-PEEP. (4) Current PSV application is limited to infant with relatively low airway resistance and RR < 40 breath/min. (OF-92-202)

Imposed Work of Breathing in 4 Pediatric Ventilators—Cyndy Miller RCP RRT, Kelvin MacDonald RCP CRTT, Kaiser Permanente Medical Center, *Los Angeles, California*; Robert Chatburn RRT, Rainbow Babies & Childrens Hospital, *Cleveland, Ohio.*

Considerable differences exist in functional characteristics of devices for mechanical ventilatory support of infants. Options may include combinations of demand flow (DF), continuous flow (CF), and pressure support (PS). We sought to describe performance in terms of imposed inspiratory work (IIW) during spontaneous breathing (SB). **Methods**: Work was calculated as integral of pressure below baseline with respect to inspired volume (Marini JJ. Probs in Crit Care 1990;4:184-199). Bird VIP, Infrasonics InfantStar, Newport Wave, & Siemens Servo 900C were each connected to active lung model (variable-speed, variable stroke-volume piston pump), with f 60, I:E 1:1, inspiratory flow 5 L/min, V_T 30 mL. Each ventilator was adjusted to provide 0, 2, & 6 cm H_2O CPAP & whichever possible options: DF alone; 3-4 , 10, & 15-16 L/min CF alone; DF with PS 2 & 4 cm H_2O; and 3 L/min CF with PS levels 2 & 4 cm H_2O. IIW defined as work required to draw gas from patient circuit was measured via VenTrak incorporating NVM hot-wire anemometer. For each possible combination of settings, 10 randomly chosen breaths were analyzed following 3-min equilibration period. **Results**: Results are mean (SD) in g · cm.

Vent/ CPAP (cm H_2O)	Demand	CF 3-4	CF 10	CF 15-16	PS 2 CF 0	PS 4 CF 0	PS 2 CF 3	PS 4 CF 3
VIP +0	9 (1)	1 (1)	1 (1)	2 (1)	7 (1)	5 (1)	∅	∅
VIP +2	6 (1)	19 (1)	2 (2)	3 (3)	2 (1)	2 (1)	∅	∅
VIP +6	3 (1)	Δ	2 (2)	2 (2)	2 (3)	0 (1)	∅	∅
Star +0	13 (2)	13 (2)	Δ	Δ	∅	∅	∅	∅
Star +2	4 (2)	5 (2)	Δ	Δ	∅	∅	∅	∅
Star +6	5 (2)	8 (2)	Δ	Δ	∅	∅	∅	∅
Wave +0	3 (2)	1 (1)	3 (2)	1 (1)	1 (1)	5 (1)	0 (0)	0 (0)
Wave +2	2 (1)	0 (0)	Δ	Δ	0 (0)	0 (0)	1 (1)	0 (0)
Wave +6	1 (1)	2 (1)	Δ	3 (2)	0 (1)	0 (1)	0 (0)	
900C +0	11 (3)	∅	∅	∅	Δ	Δ	∅	∅
900C +2	Δ	∅	∅	∅	Δ	Δ	∅	∅
900C + 6	Δ	∅	∅	∅	Δ	Δ	∅	∅

∅ = option not available on ventilator

Δ = at certain settings, demand system performed erratically producing widely fluctuating results, characterized by high frequency oscillations in pressure & flow with multiple 0 crossings within breaths.

Conclusion: We observed apparent differences in IIW among ventilators during simulated SB with DF and CF at 3-4 L/min. VIP & Wave performed similarly at high CF levels with PS. Lowest IIW observed when using PS + CF on Wave. Star behaved erratically at CF of 10 & 15 L/min. 900C erratic under all conditions except DF at 0 CPAP. Data suggest clinical studies on patients are warranted. (OF-92-108)

Jet Ventilation during Surgery: A Case Study—Darlene Casteel RRT, Timothy Black MD. Cook-Ft Worth Children's Medical Center. *Fort Worth, Texas.*

A 2.9-kg infant was born by C-section to a 24 y-old, G1, P2 whose pregnancy had been complicated by premature labor and who had been treated with terbutaline. A left congential diaphragmatic hernia was diagnosed in utero. The infant was intubated immediately after delivery and placed on conventional pressure ventilation for transport to the intensive care nursery.

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The infant was then electively reintubated with a 3.0-mm HiLo Triple Lumen Jet tube, and placed on the Bunnell Life Pulse High Frequency Jet Ventilator. Jet settings were rate 420 bpm and PIP 28, with background settings of rate 10 bpm, PIP 30, PEEP 4, F_{IO_2} 1.0. Chest x-ray revealed air-filled loops of small bowel in the left hemithorax, with the stomach located intra-abdominally. The left upper lobe was aerated, and there was a right mediastinal shift. The infant was slowly weaned resulting in pre-surgery jet settings of rate 420 bpm and PIP 18, background rate 10 bpm, PIP 22, PEEP 2, F_{IO_2} 0.40. ABG were pH 7.48, P_{CO_2} 22, P_{O_2} 314, HCO_3^- 21. Surgical repair was performed at 15 hours of age with F_{IO_2} increased temporarily to 100%. The abdomen was entered through a transverse incision, and the liver was retracted medially to allow visualization of the diaphragm. The diaphragmatic remnants were dissected and approximated. Chest excursions were minimal and O_2 saturations remained 100%. ABG was pH 7.57, P_{CO_2} 19, P_{O_2} 220, HCO_3^- 18. The infant was returned to the nursery and weaned by blood gas results until post-surgery Day 1. The infant was then placed on conventional settings of rate 25 bpm, PIP 24, PEEP 4, F_{IO_2} 0.29. On Day 2, the infant was extubated to room air. Discharge was on Day 6. We conclude that, in this instance, the use of jet ventilation during surgery was feasible, reducing the risk of barotrauma and maintaining adequate oxygenation and ventilation. (OF-92-170)

Pulmonary Function Assessments, Blood Gas Devices, Techniques, and Interpretation

Cyanosis and Sulfhemoglobinemia: A Case Report—James M O'Connor BA RCPT RPsgT RRT. Lancaster General Hospital, *Lancaster, Pennsylvania.*

Sulfhemoglobinemia (SHG) is an uncommon disorder that is often mistaken for methemoglobinemia (MHG). Both of these disorders are caused by the oxidation of the heme moiety by certain drugs and chemicals (usually in overdosage amounts). A patient developed SHG after receiving normal doses of a commonly used drug known to cause MHG. An 80-year-old Caucasian woman was referred for arterial blood gas analysis (ABG) because of cyanosis. The hue of her skin was violaceous and slightly yellow. She was asymptomatic, and no cardiac or pulmonary cause for the cyanosis could be found. Her renal function was normal. Medications included only one of note—phenazopyridine (Pyridium) 200 mg tid, a urinary tract analgesic known to cause MHG. ABGs revealed pH 7.44, P_{aCO_2} 41 torr, and P_{aO_2} 71 torr. The blood, however, was chocolate-colored. Co-oximetry (IL-282, Instrumentation Laboratories, Lexington MA) revealed a methemoglobin (MetHb) level of 42%. The Hb was 12.8 g/dL. The Pyridium was stopped and methylene blue (MB) administration begun at 1 mg/kg I.V. to reduce the MetHb. Repeat MetHb level was 40%. Repeat MB treatment failed to lower the MetHb level. Spectrophotometric analysis revealed a sulfhemoglobin (SHb) level of 18.3% and no evidence of MetHb. Neither SHb nor MetHb can carry oxygen and both can cause cyanosis. Significant differences exist, however, between the two hemoglobin derivatives. Due to its spectral characteristics, SHb can cause greater cyanosis than MetHb. As little as 0.5 g/dL of SHb causes cyanosis compared to 1.5 g/dL MetHb. Despite greater cyanosis, patients with SHG are less toxic because SHb shifts the O_2 dissociation curve to the right, thereby enhancing tissue oxygen delivery. MetHb shifts the curve to the left. As a result, patients with SHG are often asymptomatic despite SHb levels up to 60%. MetHb levels greater than 40% are often toxic. While MHG can be treated with MB, there is no antidote for SHG. SHb cannot be converted to normal Hb and lasts the life of the erythrocyte, approximately 120 days. Treatment consists of the withdrawal of the offending agent. Finally, the IL-282 does not differentiate between SHb and MetHb. SHb absorbs light of wavelengths near the value for MetHb and produces an erroneously high MetHb reading. Five months after discharge the patient's SHb level was normal (0%) and her cyanosis had disappeared. (OF-92-006)

Evaluation of a New Blood-Conserving Arterial Line System for Intensive Care Units—Mitchell J Silver DO, Hala Jubran BA, Susan Stein RN, Thomas McSweeney BS, Fuad Jubran MD. Cleveland Clinic Foundation, *Cleveland, Ohio.*

Introduction: The SafeDraw Blood-Conserving Arterial Line (SBCA) (Viggo-SpectraMed, Oxnard CA) was developed to eliminate blood loss associated with "clearing" arterial lines prior to sampling blood for laboratory testing. This evaluation tests the volume relationships inherent to the SBCA to ascertain whether blood samples drawn from the device are hemodiluted or contaminated with heparin. **Method:** 15 ICU patients with indwelling arterial lines were connected to an SBCA. A 3-way stopcock was added to the SBCA so that blood could be sampled in a conventional fashion, whereby 5 mL of blood mixed with resident heparin solution is discarded to clear the system prior to sampling for laboratory testing. Comparisons of prothrombin time (PTT) and hematocrit were then made on 3 paired samples from each patient utilizing the SBCA vs the conventional method. **Results:** A Bland-Altman bias analysis of the variability between the two blood draw methods was performed. The analysis indicated that (1) a randomly determined PTT obtained from the SBCA would lie between 3.32 and −5.11 of the PTT taken from the conventional arterial line value with 95% confidence, and (2) a randomly determined hematocrit obtained from the SBCA would lie between 1.97 and −1.85 of the hematocrit taken from the conventional arterial line value with 95% confidence. When inadequate amounts of blood mixed with resident heparin flush solution are used to clear conventionally configured arterial lines, a reduction in the measured hematocrit or artifactual prolongation of PTT values due to hemodilution and heparin contamination may adversely affect patient care. **Conclusion:** The volume relationships inherent to the SBCA provide clinically reliable blood samples for the measurement of PTT and hematocrit with no evidence of hemodilution or heparin contamination. The SBCA also provides a mechanism for blood conservation by eliminating the need to discard blood. (OF-92-017)

Reliability of Pulse Oximeters during Exercise—Tim Blanchette MS RRT, John Dziodzio BA. Maine Medical Center, *Portland, Maine.*

Introduction: Respiratory therapists in our institution noted that unrealistically low S_{pO_2} values were sometimes displayed on a portable oximeter while normal subjects were exercising. We questioned the extent of this problem. **Methods:** We tested 12 normal non-smoking volunteers (5 men) from 26-44 years of age (mean 35 y) and ranging from 115-225 pounds (mean 148 lb). 4 standard finger sensors from 4 portable oximeters (MiniOx IV, Bird 4400, Minolta/Marquest Pulsox 7, Nonin 8500) were randomly and simultaneously placed (2 on each hand) on the volunteers' digits, and ear sensors from a Biox IVA and Criticare 504US were secured with headbands for comparison. Subjects exercised on a Quinton Corival 400 bicycle ergometer at an exercise level of 50-300 watts in order to increase their pulse rate to 140-160 bpm. 2 observers recorded S_{pO_2} values at rest and at 15-s intervals during 5 min of exercise. Subjects with S_{pO_2} values > 5% from the mean ear oximeter values were retested while finger probes were secured with microfoam tape and shielded from light. **Results:** Individual S_{pO_2} values were compared to mean values for the 6 oximeters. In 8 of 12 subjects, all pulse oximeters displayed S_{pO_2} values whose mean % difference (from the 6-oximeter mean) was never > 3.05%. In this group of subjects, the maximum difference from the 6-oximeter mean did not exceed 5%, and no S_{pO_2} values were displayed 18.0% of the time on the MiniOx oximeter and 1% on the Minolta oximeter; otherwise S_{pO_2} readings were always present. In the 4 other subjects, S_{pO_2} values were > 5% from the 6-oximeter mean for 31 (3) % of readings. Minolta and MiniOx oximeters "blanked out" 10% and 29% of the time, respectively, and yielded maximum mean differences of 6.57% and 5.82%. In this group, maximum differences from the 6-oximeter mean for the other oximeters were Criticare 12.58%, Bird 8.17%, Nonin 19.01%, Biox 5.32%. When finger probes were secured and shielded with tape, number and magnitude of erroneous S_{pO_2} readings improved dramatically in 3 of these 4 subjects—mean differences were 3.67% or less in all circumstances. However, in 1 subject, 3 of the 4 oximeters with finger probes, displayed a larger mean % difference (up to 22.16% from mean) than when the sensors were not secured. **Summary & Conclusions:** Pulse oximeters may not have appropriate signal quality thresholds and thus may display erroneous readings during exercise. Taping and securing oximeter sensors in exercising patients usually reduces aberrancies. However, many factors such as probe design, signal processing errors, movement, and extraneous light, affect the reliability of pulse oximeter readings.These factors may not be easily controlled, therefore cautious judgment is necessary when interpreting pulse oximeter readings in exercising patients. (OF-92-086)

Are Oximeter Nondisposable Probe Disinfection Techniques Effective?—Martin C Wilkins BS RRT, St Vincent Hospital & Medical Center, *Portland, Oregon.*

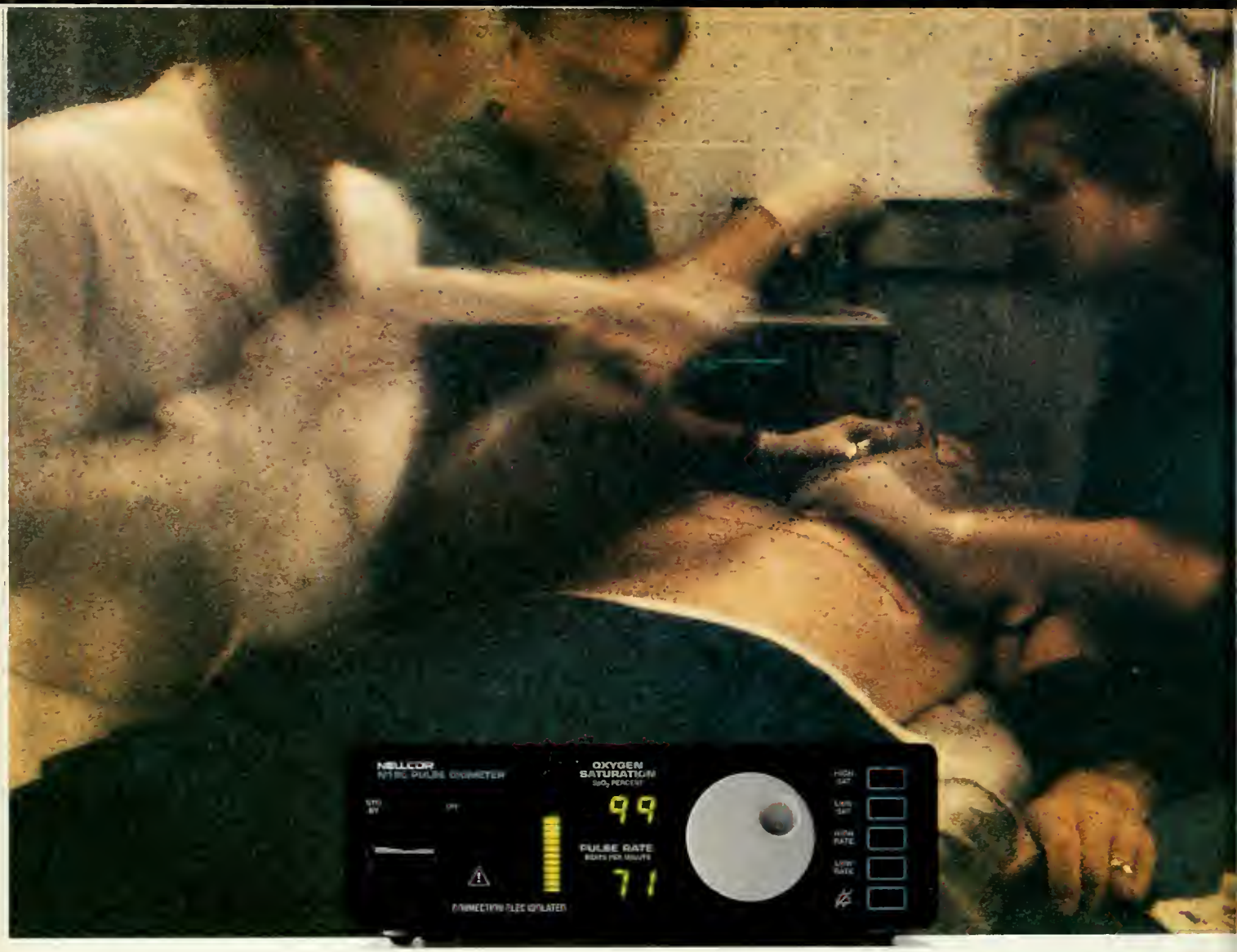
Introduction: Recent stringent Centers for Disease Control standards specify the need for proper disinfection of noninvasive monitoring equipment in the hospital setting. This led us to examine the efficacy of the commonly practiced technique of disinfecting nondisposable pulse oximeter probes with isopropyl alcohol. **Methods**: In a bench study, we used three infectious bacteria to inoculate three common nondisposable pulse oximeter finger probes—a finger clip, Y type, and straight bandage type. The test procedure consisted of inoculating a gloved hand with a high titer of *Staphylococcus aureus, Pseudomonas aeruginosa,* and *Candida albicans.* These organisms were tested independently and in triplicate with the following technique. The probe was applied to the inoculated finger for 5 minutes then removed. The probe was disinfected by wiping with a 4 × 4 cotton gauze pad soaked with a 70% isopropyl alcohol solution, starting with the cord from the proximal to the distal end, then wiping outside and inside surface of probe. The probes were assayed by an independent laboratory to determine survival of organisms before and after the disinfection procedure. **Results:**

Results (1.5 × CFU):	Inoculated Glove Control	Finger Clip Control	After Disinfection	Y Probe Control	After Disinfection	Straight Bandage Control	After Disinfection
			Staphylococcus aureus				
Total Mean	1506667	113333	77	1446667	100	38944	4701
% Reduced			99.9		99.9		87.9
			Pseudomonas aeruginosa				
Total Mean	136667	18066	12866	15178	8618	55778	2604
% Reduced			71.2		43.2		91.7
			Candida albicans				
Total Mean	4000	1092	207	584	237	289	44
% Reduced			81.0		59.4		84.8

Conclusions: The common practice of disinfection with isopropyl alcohol was effective in this study for *S aureus* only. *P aeruginosa* and *C albicans* did not meet CDC standards for a 90% reduction in colonization. We propose that improved disinfection techniques be investigated, and that when selecting nondisposable pulse oximeter probes the issue of possible cross-contamination be taken into consideration. (OF-92-144)

Dual Oximetry for Continuous Venous Admixture Monitoring in a Hypoxic Canine Model—John M Graybeal CRTT, Garfield B Russell MD. Pennsylvania State University College of Medicine, *Hershey, Pennsylvania.*

Impairment of oxygenation can be monitored in several ways. Zetterstrom (Acta Anaesthesiol Scand 1988;32:579-584) evaluated techniques and determined that venous admixture [$\dot{Q}_s/\dot{Q}_t$; $\dot{Q}_s/\dot{Q}_t = (C_{cO_2} - C_{aO_2})/(C_{cO_2} - C\bar{v}_{O_2})$] monitors oxygenation impairment accurately. Venous admixture is physiologic shunt measured while breathing any O_2 concentration (Applied Respiratory Physiology, Nunn, 3rd ed). A simplified method to monitor $\dot{Q}_s/\dot{Q}_t$, also called ventilation-perfusion index [VQI; $VQI = (1 - S_{aO_2})/(1 - S\bar{v}_{O_2})$], using small aliquots of blood & only O_2 saturation from a hemoximeter has been reported to be accurate in humans with severe hypoxic respiratory failure



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(Respir Care 1991;36:1256-1257). This simplification requires all S_{aO_2} & S_{pO_2} readings of 100% to be represented as 99.99%. We studied reliability of VQI using O_2 saturations from continuous O_2 monitors: Ohmeda 3700 pulse oximeter, PO, (S_{pO_2}) & Oximetrics fiberoptic pulmonary artery catheter, PAC, (S_{fO_2}). With Animal Utilization Committee approval, 9 mongrel dogs were anesthetized, paralyzed, & mechanically ventilated with room air. Each dog was monitored by femoral & fiberoptic PAC a 3-lead ECG, PO, & Perkin-Elmer MGA 1100 mass spectrometer. Simultaneous arterial & mixed-venous blood samples were obtained at random intervals & analyzed by Corning 168 pH/Blood Gas Analyzer & Radiometer OSM2 Hemoximeter. S_{pO_2} & S_{fO_2} were noted at time of sampling. $\dot{Q}_s/\dot{Q}_t$ was calculated from BG results. VQI was calculated using combinations of S_{aO_2}, $S\bar{v}_{O_2}$, S_{pO_2}, and S_{fO_2} in equations shown. Hypoxemia was induced by venous air embolism or prolonged breath-holding. Data were analyzed by linear regression with p value < 0.05 significant. Bias and standard deviation of differences (SDD) were calculated. 102 measurement sets were made. $\dot{Q}_s/\dot{Q}_t$ ranged from 6.9% to 89.6% [mean (SD) = 26.1% (17.3)]; S_{aO_2} and $S\bar{v}_{O_2}$ from 98.0-18.4% and 90.7-13.7%, respectively; S_{pO_2} and S_{fO_2} from 100-16% and 91-12%, respectively. Table lists results for each of 4 combinations.

Equation	Regression Equation	r Value	p Value	Bias	SOD
$(1 - S_{aO_2})/(1 - S\bar{v}_{O_2})$	$y = 0.033 + 0.94x$	0.994	0.0001	−1.7%	2.0%
$(1 - S_{aO_2})/(1 - S_{fO_2})$	$y = 0.024 + 0.95x$	0.949	0.026	−1.3%	6.7%
$(1 - S_{pO_2})/(1 - S\bar{v}_{O_2})$	$y = 0.073 + 0.64x$	0.621	0.177	1.5%	18.4%
$(1 - S_{pO_2})/(1 - S_{fO_2})$	$y = 0.070 + 0.66x$	0.612	0.245	2.0%	16.0%

Using S_{aO_2} and $S\bar{v}_{O_2}$ measured with hemoximeter, VQI demonstrated significant correlation with $\dot{Q}_s/\dot{Q}_t$ Substituting S_{fO_2} for $S\bar{v}_{O_2}$ produced similar significant correlation between VQI and $\dot{Q}_s/\dot{Q}_t$. When values for PO (S_{pO_2}) are used to replace S_{aO_2}, correlation is poor (p = 0.177 and 0.245, respectively) between $\dot{Q}_s/\dot{Q}_t$ and VQI. Although bias is small for all equations, large SDD values when S_{pO_2} is incorporated into equations demonstrate a wide variation between $\dot{Q}_s/\dot{Q}_t$ and VQI. These data suggest that estimating $\dot{Q}_s/\dot{Q}_t$ with VQI using small aliquots of blood or combination of arterial blood and fiberoptic PAC is useful, but continuous estimations of $\dot{Q}_s/\dot{Q}_t$ using PO, for continuous S_{pO_2}, is not reliable. (OF-92-153)

Alterations in Respiratory Pattern Do Not Explain Arterial Hypoxemia in Postoperative Patients—John M Graybeal CRTT, Garfield B Russell MD. Pennsylvania State University College of Medicine, *Hershey, Pennsylvania.*

Arterial hypoxemia occurs frequently following surgery. Occurrence of postoperative arterial oxygen desaturation (AOD) has been documented, using intermittent monitoring of arterial oxygen saturation (S_{aO_2}), during transport to & stay in post-anesthesia recovery room (PACU). Purpose of study was to determine, in population of healthy patients undergoing elective surgery, incidence of AOD, as defined as S_{aO_2} < 92% for > 30 s, using continuous monitoring of S_{aO_2}, & to correlate these events with incidence of hypoventilation as defined by decrease in respiratory rate > 20% or a change in the end-tidal CO_2 by > 10%. With approval from institutional clinical investigation committee, 134 PACU patients, from time of admission to discharge from PACU, were evaluated continuously for occurrence of AOD with either Nellcor N-200 or N-1000. Patients were transported to PACU spontaneously breathing room air & on admission were given O_2 (F_{O_2} = 0.40) by face tent at 12 L/min. Routine PACU care was not interrupted, & personnel were not blinded to S_{aO_2}. Nasal P_{etCO_2} was monitored continuously in 34 patients using either a Beckman LB3 or Nellcor N-1000 infrared capnometer. Data are presented as mean (SD) where applicable. Data analysis was by multiple regression analysis, with p < 0.05 considered significant. 137 AOD events were recorded in 39 patients [3.5 (3.7) events/patient]. Desaturations occurred at 31 (49) min following admission to level of 87.5 (3.6) % & lasted 3.1 (9.4) min. 54% of AODs occurred during O_2 administration. Factors correlating positively with episodes of AOD include peripheral surgical procedures (p = 0.02), duration of anesthesia (p = 0.04), & intraoperative intravenous fluid volume (p = 0.001). Duration of AOD correlated with sex (female; p = 0.05), body weight (p = 0.02), & intraoperative intravenous fluid volume (p = 0.02). In 34 patients monitored for hypoventilation, 69 desaturations occurred [4.9 (5.1)/patient], 34 (46%) with changes in $etCO_2$ and 23 (33%) with decreases in respiratory rate. Mean incidence/patient of AOD occurring with $etCO_2$ changes was 24.6% and with decreases in respiratory rate 19.3%. The same patient often exhibited separate AOD events with or without signs of hypoventilation. We have demonstrated a significant incidence of AOD in PACU patients that may not necessarily be associated with signs of hypoventilation. High incidence of AOD suggests that a more individualized O_2 therapy regimen is needed in PACU. Lack of significant correlation between hypoventilation & all AOD events suggests different mechanisms contribute to AOD in same patient—including increased venous admixture, decreased FRC, upper airway obstruction, & respiratory depression. These data support findings of Tulla et al (Acta Anaesthesiol Scand 1992;36:101-105) that changes in breathing patterns postoperatively did not explain alterations in gas exchange & decreases in arterial oxygenation following hip surgery. (OF-92-154)

Evaluation of a Bedside On-Demand, Ex-Vivo Arterial Blood Gas Monitoring System in Critically Ill Patients—Barry A Shapiro MD, William T Peruzzi MD, ML Franklin MD, Northwestern Memorial Hospital, *Chicago, Illinois*; RD Cane MB BCh, University of South Florida, *Tampa, Florida.*

Recent advances in fluorescent optode technology have enabled development of bedside, rapid, on-demand, ex-vivo arterial blood gas (ABG) monitoring. The microprocessor-controlled, fluorescent optode blood gas (ABGfo) monitoring system (System 2000, CDI-3M Health Care) incorporates a light souce connected to a cuvette via an optical fiber system. The sterile, heparin-bonded, non-pyrogenic cuvette contains 3 individual fluorescent microsensors (pH, P_{CO_2}, & P_{O_2}) & a

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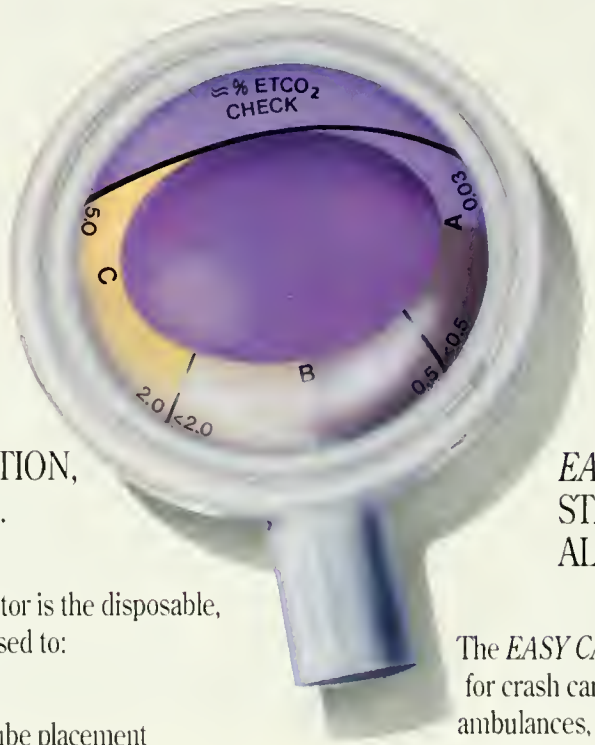

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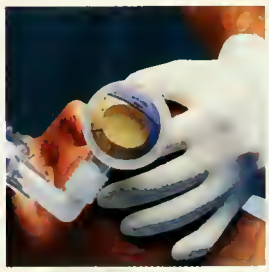

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thermister contact surface for temperature measurement. The ABGfo system underwent a 2-point gas calibration & was placed in series with tubing of indwelling arterial catheters in 45 critically ill patients. While obtaining an arterial sample for conventional measurement of a clinically indicated ABG, blood was drawn through the System 2000 sensor, which measured pHa, P_{aCO_2}, & P_{aO_2} after 90 seconds of equilibration. 504 paired ABG values measured by conventional analysis (ABGc) and ABGfo system were analyzed for correlation & agreement. Mean (SD) ABGc measurements were pH_a 7.41 (0.006), P_{aCO_2} 39 (5.6) torr, and P_{aO_2} 96 (44) torr. Mean ABG -fo measurements were pH_a 7.42 (0.06), P_{aCO_2} 40 (6) torr, and P_{aO_2} 99 (41) torr. Correlation between ABGc and ABGfo was excellent (R^2 was 0.84 for pH_a, 0.84 for P_{aCO_2}, and 0.96 for P_{aO_2}). Mean (SD) differences between ABGfo values were 0.004 (0.025) for pH_a, 0.9 (2.3) torr for P_{aCO_2}, and 2.8 (9.9) torr for P_{aO_2}. We conclude that bedside ABGfo monitoring system is an accurate alternative to conventional ABG analysis. This system offers the advantage of providing rapid results with reduced blood sampling, handling, and wastage. (OF-92-198)

Influence of Radial Artery Catheters on Pulse Oximetry in Cannulated versus Non-Cannulated Hands—Richard Hoskins CPFT RRT, John S Sabo MS RRT, Joy E Hargett BS RRT, Elizabeth Bearden AAS RRT. St Luke's Episcopal Hospital, *Houston, Texas.*

Study Question: Does the use of radial artery catheters (RACs) influence the performance of pulse oximetry in the cannulated versus non-cannulated hand? **Method:** 342 postoperative (postop) patients (pts), age range 21-80 (mean age 59.4), in our cardiovascular recovery room (CVRR) were divided into 3 groups: Group I, pts with right RACs (n = 71); Group II, pts with left RACs (n = 211); Group III, evaluation of pulse strength (n = 42). CVRR pts with indwelling RAC inserted in the operating room were placed on Novametrix 505 or 515 pulse oximetry monitors (Novametrix Medical Systems Inc). Monitors were placed on either hand, regardless of right or left dominance. All patients had warmed to > 35°C core temperature prior to data collection, to ensure that peripheral circulation was adequate for pulse oximetry. Paired simultaneous measurements were done on the same phalanx of both hands (ie, index finger, ring finger), and saturation data were collected. Due to the pulse oximeter software and the superbright probes, pulse strength relative to the opposing hand was impossible to collate. Pulse strength is defined as proportional to the natural logarithm of the ratio of pulse amplitude to mean infrared signal strength [Anaesth Intensive Care 1990;18(1)]. Pulse strength in 42 of the pts using a Nellcor N-10 pulse oximeter was evaluated. **Results**: Group I, mean S_{pO_2} 97.3% (range 93-100%). Group II mean S_{pO_2} 97.1% (range 92-100%). Maximum difference of right and left hand was 2%. Group III, relative pulse strength in the right hand (21 pts) was 13.7 vs 13.69 in the left hand (21 pts). **Conclusion**: It was determined that there are clinically unimportant differences in results of pulse oximetry in cannulated versus non-cannulated hands in CVRR postop pts. (OF-92-176)

A Method of Preoperative Lobectomy Evaluation on a Chronically Hypoxemic Subject Who Breathes Near Closing Capacity—Harold B Winnike BS RPFT RRT, Keith R Momii MMSc RPFT RRT, Akhil Bidani MD PhD. University of Texas Medical Branch, *Galveston, Texas.*

Introduction: A 62-year-old white woman, Ht 68 in, Wt 190 lb, with a 90 pack-year smoking history & a diagnosis of adenocarcinoma was referred to our pulmonary clinic to evaluate operability (right lower lobectomy). Spirometry showed mild obstructive ventilatory defect (FEV_1 79% of predicted, FEV_1/FVC ratio 67%, FEF_{25-75} 36% of predicted) with no important bronchodilator response. Initially it was felt she was unresectable, because ABG revealed chronic compensated metabolic alkalosis with severe hypoxemia on room air (pH 7.43, P_{aCO_2} 43 torr, P_{aO_2} 53 torr). A shunt study on 100% oxygen was within normal limits. Additionally, plethysmographic measurements of lung volumes indicated a markedly reduced ERV. Another blood gas was drawn after the patient took 5 deep breaths. The P_{aO_2} increased to 96 torr, suggesting that she breathes at or near her closing capacity resulting in partial airway closure at the bases. **Method**: In order to determine resectability, CPAP was utilized in conjunction with a body plethysmograph as a means of further preoperative evaluation. A transmural pressure/flow plethysmograph (SensorMedics 2800) was used to measure absolute lung volumes in seated position while patient received increasing levels of CPAP applied with Respironics SleepEasy III through transmural breathing port of plethysmograph. **Results**: At 10 cm H_2O the FRC increased 0.53 L from baseline (2.61 L to 3.14 L) with the appearance of an ERV (50 mL) and a concomitant rise in P_{aO_2} to 76 torr. CPAP was increased to 15 cm H_2O with subsequent increase of 0.86 L in FRC from baseline (3.47 L). P_{aO_2} did not change significantly (75 torr). ERV increased to 0.91 L. **Discussion**: Additional measurements of FRC using CPAP clarified etiology of this patient's severe hypoxemia, which was concluded to be from her breathing near closing capacity, resulting in basalar atelectasis and profound ventilation/perfusion inhomogeneities. These additional findings led to a re-evaluation of the patient's operability. The patient underwent lobectomy with no intraoperative or perioperative problems. Postoperative ABG on CPAP was not obtained; however, her last ABG on room air revealed a P_{aO_2} of 62 torr (pH 7.40, P_{aCO_2} 40 torr). Due to the insignificant change in pre- and postoperative P_{aO_2} (53 torr and 62 torr, respectively), the resected lobe was an unlikely contributor to the $\dot{V}/\dot{Q}$ inequality. However, in the absence of quantitative $\dot{V}/\dot{Q}$ scan, this cannot be conclusive. **Conclusion**: We have described a role of CPAP for preoperative evaluation (pulmonary resection) in a chronically hypoxemic patient who breathes near closing capacity. The ability to demonstrate increased FRC, ERV, and P_{aO_2} by providing CPAP was also helpful in the perioperative and postoperative management of this patient. (OF-92-013)

Effects of Recreational Scuba Diving on Respiratory Function—Jacalyn J Robert PhD, Richard D DeBenedetto MEd CRTT, James F McNally MEd, Roy Wolfe PhD, Mike Bobo PhD. Texas Tech University and Texas Tech University Medical School, *Lubbock, Texas.*

It has been shown that ventilatory muscles fatigue in response to exhaustive work just as other skeletal muscles & that ventilatory muscle fatigue may be one factor involved in determination of tolerance to exercise. What remains unclear is what types of exercises produce measurable changes in respiratory muscles. We hypothesized that recreational scuba diving would increase ventilatory muscle strength & thereby improve respiratory function. 83 students enrolled at Texas Tech University were enlisted. Treatment group consisted of 31 participants enrolled in a scuba diving course. Respiratory variables measured in both treatment & 52 randomly selected at-large control subjects were FVC, FEV_1/FVC, MIP, MEP. Quantification was via 9-L Respirometer (Collins) and Bugle Manometer (Applied Engineering). In treatment group, training consisted of twice/wk for 10 wks scuba diving (average depth 337 cm, total underwater time 982 min). Exclusion criteria for all: pulmonary disease by history & physical exam, enrollment in exercise training program in 6 mo prior to study. Controls were utilized to monitor for preselection bias & ensure equivalency of treatment and control groups. Independ *t* test comparing change score (pretest-posttest) between treatment & control groups was used. Invalid or unfeasible changes were not used in analysis. A greater but not significant pre-to-post improvement was noted in treatment group compared to control for all variables tested. [FVC $t(61) = 0.99$, $p > 0.05$; FEV_1/FVC $t(67) = 0.7$, $p > 0.05$, MIP $t(77) = 1.05$, $p > 0.05$. Significant difference was found for MEP $t(66) = 2.23$, $p < 0.05$.] Findings are in agreement with others who have found that swimmers have larger VC due to respiratory resistance training from underwater exhalation. (OF-92-114)

Monitoring the Mechanically Ventilated Adult Patient

Measurement of Spontaneous Breathing Parameters in Mechanically Ventilated Patients: A Comparison of Two Methods—Mauo-Ying Bien MS RPT CRTT, Chia-Chen Chu BS RT, Jia-Horng Wang MD, Jen-Ru Chen RT, I-Nen Lin RT, Shiau-Bey Jou MBA. Veterans General Hospital-Tapei, *Taipei, Taiwan, Republic of China.*

Spontaneous breathing parameters such as P_{Imax}, $\dot{V}_E$, RR, and calculated V_T are the usual criteria for weaning from mechanical ventilation. The sequence of these measurements differs. Some clinicians measure P_{Imax} first and then $\dot{V}_E$ and RR (Method A) to get the highest P_{Imax}. Others measure $\dot{V}_E$ and RR first because this way is easier to perform and less stressful (Method B). This study aimed to determine whether both methods might produce different results of measurement or different incidence of adverse reaction. Using Methods A and B, 52 sets of spontaneous parameters were measured in 48 adult mechanically ventilated patients who were in stable condition. Four patients were measured twice. In randomized choice of sequence, measurements with different methods were conducted at least 10 min apart to ensure the patient's condition returned to baseline (S_{aO_2}: ± 2%, PR: ± 10/min). Oxygen saturation, PR, and breathing pattern were monitored before, during, and after each treatment. Adverse reactions were defined as PVC ≥ 5/min, (2) HR increasing over 20/min from baseline, (3) HR decreasing over 20/min from baseline, and (4) desaturation ($S_{aO_2} \leq 85\%$). Paired *t* test was used to compare the results from different methods. Fisher's Exact Test was used to compare the difference in incidence of adverse reaction; $p < 0.05$ was considered significant. Measurements with Methods A and B were found significantly different in $\dot{V}_E$ (9.70 ± 3.16 L/min vs 8.41 ± 2.92 L/min) and RR (27.85 ± 7.51/min vs 26.27 ± 8.58/min; $p < 0.05$), but not in P_{Imax}. No difference was found when patient's age, sex, past history of COPD, neuromuscular or cardiac disease were taken into account, but P_{Imax} differed significantly with differences in level of conciousness (conscious patients: P_{Imax} A < P_{Imax} B; unconscious patients: P_{Imax} A > P_{Imax} B). Also, significant difference in incidence of adverse reaction was found between both methods (15.38% in Method A vs 21.15% in Method B, $p < 0.05$). In conclusion, when measuring spontaneous breathing parameters, Method A produced higher $\dot{V}_E$ and RR and induced fewer adverse reactions than Method B. (OF-92-033)

Comparison of Two Methods To Measure Auto-PEEP during Mechanical Ventilation—Dean Hess MEd RRT, Gregory Matte, Daniel Deao, Mark Simmons MSEd RPFT RRT. York Hospital and York College, *York, Pennsylvania.*

Introduction: Although auto-PEEP (intrinsic PEEP, $PEEP_i$) may occur frequently in adult mechanically ventilated patients (Respir Care 1986;31:1069), it remains difficult to identify and quantify. The presence of $PEEP_i$ can be identified by failure of end-expiratory flow to return to zero. It can be quantified by measuring the pressure at the airway opening (P_{ao}) during an end-expiratory pause (pause method: Am Rev Respir Dis 1982;126:166), or by measuring the P_{ao} required to generate positive flow at the initiation of inspiration (flow method; Am Rev Respir Dis 1985;131:672). The purpose of this study was to compare these methods for measuring $PEEP_i$. **Methods:** The experimental setup consisted of a Servo 900C ventilator, a Michigan Instruments TTL test lung, and a calibrated Med-Science VenTrak Lung Mechanics Analyzer. $PEEP_i$ levels of ≈ 0-20 cm H_2O were produced by varying the inspiratory time (25%, 33%, 50%, 60%, 70%, 80%), test lung compliance (0.01 and 0.05 L/cm H_2O), and resistance (endotracheal tube sizes 5- and 7-mm ID). A tidal volume of 1.0 L, rate of 15/min, and set PEEP of 0 were used. The end-expiratory pause control of the Servo 900C was used to measure $PEEP_i$ by the pause method. Simultaneous recordings of flow, pressure, and volume were printed from the VenTrak. From these hard copy recordings, $PEEP_i$ was manually determined at each combination of settings using both the pause and flow methods. Measurements were repeated using three ventilators. After eliminating those

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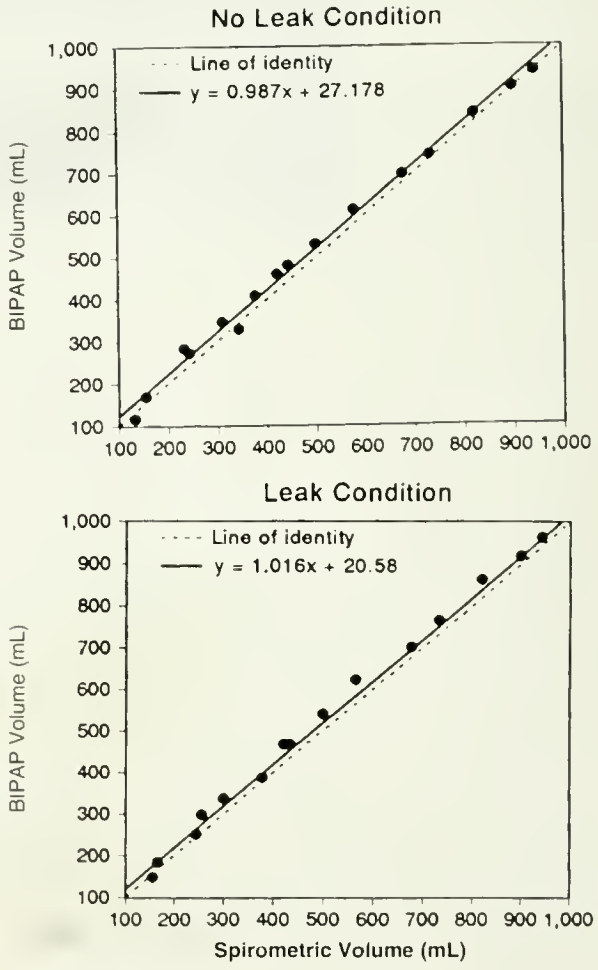
$PEEP_i$ levels that exceeded our range of interest (≈0-20 cm H_2O), 64 pairs of measurements remained for further analysis. **Results**: The correlation between the $PEEP_i$ measurements by the two methods was r = 0.993, and there was no significant difference between the $PEEP_i$ by the two methods (p = 0.439 by paired *t* test). The mean (SD) difference between the flow and pause methods was 0.08 (0.8) H_2O cm, which produces limits of agreement of −1.52 to 1.68 cm H_2O. **Conclusions**: Using this single lung unit model, the pause and flow methods are equally acceptable to measure $PEEP_i$ during passive mechanical ventilation. It should be noted that neither method is valid during active breathing (ie, the patient must be breathing in synchrony with the ventilator). The principal advantage of the pause method is its ease of use with a ventilator that allows an end-expiratory pause (such as the Servo 900C). The principal advantage of the flow method is that it allows breath-by-breath measurement of $PEEP_i$ without any changes to the ventilatory pattern of the patient. Further work is needed to compare these methods in mechanically ventilated patients. (OF-92-046)

A Method To Evaluate Changes in Airway Resistance during Mechanical Ventilation—Richard M Ford BS RCP RRT, F Wayne Johnson RCPT RPFT CRTT, David Burns MD. UC-San Diego, *San Diego, California.*.

The observation of the difference between peak inspiratory pressure (PIP) and plateau pressure has gained widespread acceptance as a method to evaluate airway resistance (R_{aw}) in patients on mechanical ventilation. When flow is constant, a decrease in R_{aw} results in a decrease in PIP at the same tidal volumes. At UCSD greater than 95% of patients are ventilated utilizing a decelerating flow pattern, and significant changes in R_{aw} can occur with minimal change in PIP. We were seeking a method to evaluate R_{aw} without having to change the flow profile to a square waveform. We tested a method labeled the "Waveform Subtraction Technic." **Method**: A P-B 7200 was set up to ventilate a test lung with a compliance of 33 mL/cm H_2O. Ventilator settings were V_T 750, RR 12, peak flow 60 with a decelerating waveform. R_{aw} was changed in increments of 1 cm H_2O/L/s regulated by an adjustable Hoffman clamp across a 9-mm ET tube. Measurements of airway flow and pressure were made after each change in R_{aw} utilizing a computer-operated data acquisition system (CODAS) sampling at a rate of 250 Hz and stored on a 386-33 microcomputer (AST Research, Irvine CA). Observations of PIP were also obtained at each level. Pressure data points for breaths with different R_{aw} were matched by the time elapsed following the onset of inspiratory flow and subtracted from each other. The pressure differences were plotted against instantaneous flow. **Results**: With incremental changes in R_{aw}, from 8 to 20 cm H_2O/L/s, there was no significant change in the PIP (PIP increased from 21 to 22 cm H_2O). The waveform subtraction plot, however, indicated a response with R_{aw} changes as small as 1 cm H_2O/L/s. A distinct and recognizable pattern resulted as the difference between the pressure waveforms of compared breaths widened as flow increased. The change in pressure was most pronounced at the point of peak inspiratory flow occurring at the start of inspiration. Actual changes in R_{aw} or the slope of the pressure difference can then be calculated. **Conclusion**: The Waveform Subtraction Technic provides a means of comparing the shape and contour of pressure waveforms and identifying patterns reflective of changes in R_{aw} that may not be detected by observations of PIP. Because the flow-time profiles for these breaths were identical, the differences in airway pressure at given times during inspiration are proportional to differences in R_{aw}. (OF-92-068)

Volume Monitoring Accuracy with the Respironics BiPAP S/T-D Detachable Control Panel—Michael S Benson BS RRT, Michael J Bishop MD. Harborview Medical Center, *Seattle, Washington.*

Introduction: Temporary nasal mask ventilation via a BiPAP (Respironics Inc) ventilator is becoming increasingly popular for hospital use. A recently available volume monitor (VM) for use with the BiPAP S/T-D ventilator uses an algorithm to calculate an expiratory tidal volume even in the face of leak around the nasal mask. We tested accuracy of device and of algorithm. **Methods:** We used a 'spontaneous breathing' model (SBM) to test the VM. A BiPAP S/T-D ventilator in spontaneous mode equipped with VM was attached to a VT−1 test lung



modified with lift bars and bellows to simulate spontaneous breathing. The lift bellows was powered by a Hamilton Veolar ventilator with a sine-wave flow pattern. SBM was adjusted to trigger BiPAP breaths at 14/min at test-lung compliance of 0.05 L/cm H_2O. Displayed BiPAP volumes were compared to test lung values under 16 different inspiratory (IPAP) and expiratory (EPAP) pressure levels. At each pressure level, VM was tested in simulated mask leak and no-leak conditions. Leak was controlled with a screw clamp at 6-8 L/min under all conditions. IPAP levels tested ranged from 8-20 cm H_2O and EPAP levels ranged from 2-12 cm H_2O. The highest displayed volume seen on the VM was compared to VT–I test lung values corrected to BTPS. VM calculated volumes were compared to spirometric volumes using linear regression analysis. Mean coefficient of variation was defined as SD ÷ mean volume. **Results**: Tidal volumes generated under test conditions ranged from 133-979 mL. In no-leak condition, VM volumes correlated well with test lung values ($r = 0.997$, $p < 0.01$). Correlation in the leak condition was also good ($r = 0.998$, $p < 0.01$). The mean coefficient of variation under all conditions was < 2%.**Conclusions**: The VM available with BiPAP S/T-D ventilator is precise and accurate under our test conditions and appears acceptable for volume monitoring during in-hospital BiPAP therapy. (OF-92-132)

A New Metabolic Monitor Validated during Time-Cycled Pressure Ventilation (TCPV)—F Wayne Johnson CRTT RPFT RCPT, K Knaus Kinninger RCP RPFT, Kathy Jacobson RCP CCVT, David M Burns MD. UC-San Diego Medical Center, *San Diego, California.*

Introduction: Measurements of oxygen consumption ($\dot{V}_{O_2}$) and carbon dioxide production ($\dot{V}_{CO_2}$) utilizing expired gas has remained clinically desirable but technically elusive for severely hypoxic lung injury patients on TCPV. In laboratory simulations, we validated a new open-circuit metabolic monitor, P-B 7250 (Puritan-Bennett). During TCPV, we examined whether changes in I:E, rate, and PIP influence accurate measurements of $\dot{V}_{O_2}$ and $\dot{V}_{CO_2}$. **Methods:** N_2 and CO_2 were infused into a constructed lung model at known rates to simulate $\dot{V}_{O_2}$ and $\dot{V}_{CO_2}$ at 300 mL/min STPD. The infusion of N_2 and CO_2 was kept constant using a series of precision flowmeters and needle valves (Gilmont). Accuracy of the flow controller system was verified volumetrically before and after each trial. Independent F_{IO_2} measurements were made with 1100a mass spectrometer (Perkin-Elmer) for the purpose of calculating predicted $\dot{V}_{O_2}$. Mechanical ventilation of the lung model was controlled by P-B 7200a ventilator with bacterial filter, heated wire circuit, and SCT 2000 humidifier (Marquest Medical). Stability of delivered F_{IO_2} was maintained with an in-line mixing chamber (Cascade I with tower). The P-B 7200a was set at TCPV mode and test combinations of I:E 1:1, 2:1, 3:1, 4:1; rate 10, 15, 25; F_{IO_2} 0.21, 0.40, 0.60; and PIP 30, 60 cm H_2O. **Results**: Laboratory simulation using N_2 and CO_2 infusion resulted in an overall mean error of 3.17 (2.85) % in $\dot{V}_{O_2}$ and 1.26 (1.49) % in $\dot{V}_{CO_2}$. The range of I:E, rate, and PIP had a minimal effect on accuracy of $\dot{V}_{O_2}$, except when F_{IO_2} increased to 0.60, which reduced accuracy slightly in mean error to 5.50 (3.49) %. The mean error of $\dot{V}_{CO_2}$ was minimally affected by I:E, rate, and F_{IO_2}, whereas increasing PIP 30 to 60 cm H_2O reduced the accuracy slightly –0.2 (1.4) % to 2.6 (1.7) %. Mean error of measurement was calculated as (measured-predicted/predicted) and expressed as percentage with all results expressed as mean (SD) %. **Conclusion**: The P-B 7250 in laboratory simulation provided accurate and reproducible measurements of $\dot{V}_{O_2}$ and $\dot{V}_{CO_2}$ during TCPV with clinically selected range of I:E, F_{IO_2}, rate, and PIP. (OF-92-146)

Use of Mixing Chamber for Stability of Delivered F_{IO_2} during the Laboratory Validation of Three Metabolic Monitors—F Wayne Johnson CRTT RPFT RCPT, K Knaus Kinninger RCP RPFT, Kathy Jacobson RCP CCVT, David M Burns MD. UC-San Diego Medical Center, *San Diego, California.*

Introduction: Stability of delivered F_{IO_2} is essential for indirect calorimetry (IC) measurements when used during mechanical ventilation [Crit Care Med 1982;10(2):82]. Use of an in-line mixing chamber placed on inspiratory side of circuit has been recommended as a method of stabilizing F_{IO_2} delivery via 7200a ventilator [Respir Care 1991;36(11): 1274,1277 and JPEN 1992;16(1):335]. We validated 3 IC systems, P-B 7250 (Puritan-Bennett), Deltatrac (Datex/SensorMedics), and Metascope (Cybermedic), in a laboratory simulation model to examine whether changes in volume of an in-line mixing chamber, F_{IO_2}, and V_T influence accurate measurements of $\dot{V}_{O_2}$ and VC. **Method**: N_2 and CO_2 were infused into a constructed lung model at known rates to simulate $\dot{V}_{O_2}$ and $\dot{V}_{CO_2}$ at 0.300 L/min. Flow of N_2 and CO_2 was monitored with a series of precision flowmeters and needle valves (Gilmont). Accuracy of flow-controller system was verified volumetrically before and after each trial. Measurements of F_{IO_2} were made independent of the IC analyzer during validations with an 1100a mass spectrometer (Perkin-Elmer). Independent analysis of F_{IO_2} was made for purpose of calculating a gold standard $\dot{V}_{O_2}$. Ventilation of lung model was controlled by 7200a ventilator (Puritan-Bennett), at setting of CMV, ramp wave, F_{IO_2}, $\dot{V}$ 60 L/min, inspired humidity (35°C), and combination of V_T 0.750, 1.0, 1.25 L with F_{IO_2} 0.21, 0.40, 0.60. Each IC trial run was conducted with a small-volume mixing chamber SCT humidifier (Marquest) followed by a trial run with the large-volume mixing chamber Cascade I with tower (Puritan-Bennett). **Results**: Mean error of measurement was calculated as (measured-predicted/predicted) values and expressed as percentage. $p < 0.05$ value differs from small-volume mixing chamber. All results expressed as mean (SD) %, calculated CI, using t value for appropriate degree of freedom × SEM:

	$\dot{V}_{O_2}$			$\dot{V}_{CO_2}$		
	P-B	DT	MS	P-B	DT	MS
Small-Volume Mixing Chamber						
Mean (SD)	4.44 (2.79)	0.07 (4.21)	–2.31 (2.12)	–0.65 (1.26)	0.69 (3.31)	0.38 (1.02)
CI	0.71	1.06	0.52	0.37	0.86	0.24
Large-Volume Mixing Chamber						
Mean (SD)	0.13 (2.21)	–1.54 (3.28)	–1.92 (1.53)	1.73 (1.38)	1.06 (2.75)	–0.97 (0.63)
CI	0.71	1.06	0.52	0.37	0.86	0.24

Conclusion Use of Cascade I with tower as an in-line mixing chamber for stability of delivered F_{IO_2} is recommended for P-B 7250, and SCT humidifier with wick or a Cascade with tower is recommended for Deltatrac and Metascope. (OF-92-147)

Ventilating Neurointensive Care Patients: The Effect of Intrathoracic Pressure on Cerebral Perfusion—John M Graybeal CRTT, Garfield B Russell MD. Pennsylvania State University College of Medicine, *Hershey, Pennsylvania.*

Cerebral ischemia causes neurologic deterioration in neurointensive care (nICU) patients as a result of decreased cerebral perfusion pressure (CPP), difference between mean arterial blood pressure (ABP) and intracranial pressure (ICP). Shapiro and Marshall demonstrated that PEEP caused decreased CPP and hypothesized mechanism to be increased intrathoracic pressure (J Trauma 1978;18:254-256). Intrathoracic pressure is increased by increases in both peak ($P_{aw}P$) and mean ($M_{aw}P$) airway pressures. We tested hypothesis that increased $P_{aw}P$ would decrease CPP in mechanically ventilated nICU patients. Following Clinical Investigations Committee approval, 5 stable male [mean (SD) age = 37.6 (21.1)] nICU patients (2 isolated closed-head injury, 3 post-craniotomy) were studied. All patients had arterial catheter for continuous measurement of BP, Camino V420 (Camino Labs) catheter for continuous measurement of ICP, and infrared capnometer (Hewlett Packard 78520A) for measurement of end-tidal carbon dioxide ($etCO_2$). Ventilation was provided by Servo 900C (Siemens Life Support Systems). All patients were ventilated with SIMV prior to study period with V_T 10-12 mL/kg, respiratory rate 8-12 bpm, and F_{IO_2} range 0.5-0.6 to maintain $S_{aO_2} > 96\%$, and I:E of 1:2. 1 patient required PEEP 2.5 cm H_2O. No patient demonstrated spontaneous respiratory efforts. To reduce $P_{aw}P$ while minimizing changes in other ventilatory variables, pressure control (PC) was used with pressure level chosen to maintain same delivered V_T measured at patient's airway during SIMV. During study phase, patients were randomly placed on PC or SIMV for 30 min, and then changed to alternate mode for additional 30 min. $P_{aw}P$ and $M_{aw}P$, ABP, ICP, CPP, $etCO_2$, S_{aO_2}, and RR were measured and recorded every 5 min during each ventilatory condition. Data were compared using paired *t* tests, with $p < 0.05$ considered significant. $P_{aw}P$ was lower during PC [22.6 (2.1) cm H_2O] than SIMV [35.0 (3.2) cm H_2O, $p = 0.0001$]. Despite this, PC resulted in higher $M_{aw}P$ than SIMV ($p = 0.0001$). There was slightly lower $etCO_2$ during PC [29.5 (3.9) torr] than SIMV [32.4 (4.3) torr, $p = 0.049$]. There were no differences in other respiratory parameters, ABP, ICP, or CPP. With constant V_T and I:E, in stable nICU patients CPP is unaffected by alterations in $P_{aw}P$. Slight reduction in $etCO_2$ did occur, without altering CPP. Further investigations into effect of alterations in $P_{aw}P$ on cerebral perfusion pressure during more labile period prior to stabilization are warranted—any benefit from decreased $P_{aw}P$ on CPP may have been masked by increased $M_{aw}P$ seen during PC. Further investigation is needed to separate these factors. Our data suggest that altering $P_{aw}P$ with PC does provide adequate ventilation but does not improve CPP in stable nICU patients. (OF-92-155)

Method Comparison of Bedside Respiratory Rate Determined by Capnometric vs Impedance Analysis on the Hewlett-Packard Monitoring System—Stephen J Connell BA RRT, Jim Holian, Julia Mutch RN MSN CCRN, Herbert Patrick MD. Thomas Jefferson University Hospital. *Philadelphia, Pennsylvania.*

Integrated bedside monitoring systems offer a wide variety of data parameters and memory capabilities, allowing data retrieval and analysis. These data may be useful for teaching, reviewing prior unwitnessed events, or research. Our hospital currently utilizes a Hewlett-Packard system (Display Monitor M1094A, Computer Module Unit M1046A, Central Display Monitor 78510A, Desk Jet Printer 500) with capability to monitor, store, and report data on respiratory rate collected by 2 independent methods. First method utilizes 2 ECG electrodes placed on chest wall and calculates respiratory rate (RESP) from changes in thoracic impedance. Second method utilizes mainstream capnometry to calculate airway respiratory rate (AWRR). We compared the 2 techniques. Ten mechanically ventilated ICU patients were selected and placed on capnometers (HP 14365A airway adapter, HP 14360A sensor) calibrated per manufacturer's recommendations. All ICU patients utilized the impedance monitor. Data were collected from central system memory for 12 consecutive hours in 90-min expanded-trend printouts, and were manually analyzed for both AWRR and RESP at 10-min intervals. Difference between methods was tabulated by subtracting RESP from AWRR and by computing mean, SEM, and 95% confidence intervals (CI) for each patient. Total time of monitor-data acquisition for each method was calculated as percentage of total study time.

		AWRR – RESP (breaths/min)		Functioning Time (%)	
Pt	n	Mean (SEM)	95% CI	AWRR	RESP
1	71	−5.04 (0.90)	−6.79 to −3.30	98.6	98.9
2	66	−2.62 (0.43)	−3.45 to −1.79	96.4	96.4
3	71	−2.23 (0.60)	−3.41 to −1.05	94.7	96.8
4	72	−1.85 (1.02)	−3.84 to 0.14	99.6	97.4
5	68	−1.12 (0.38)	−1.87 to −0.37	94.6	94.9
6	70	0.30 (0.08)	0.14 to 0.46	95.8	95.8
7	71	0.52 (0.20)	0.11 to 0.91	97.3	97.0
8	68	0.65 (0.29)	0.08 to 1.22	95.8	96.1
9	67	2.55 (0.56)	1.45 to 3.65	79.0	80.5
10	63	4.90 (0.63)	3.66 to 6.14	87.8	94.0

Our data suggest good correlation between methods in 9/10 patients with mean difference < 5 breaths/min. The Hewlett-Packard monitor offers accuracy comparable to respiratory rates derived by capnometry. (OF-92-192)

Bedside Assessment of Pressure Support Weaning with the Bear 5 Ventilator vs T-Piece—Stephen J Connell BA RRT, Gail Quenzel RRT, Dorisanne D Miller RRT, Gary Gradwell RRT, Herbert Patrick MD. Thomas Jefferson University Hospital, *Philadelphia, Pennsylvania.*

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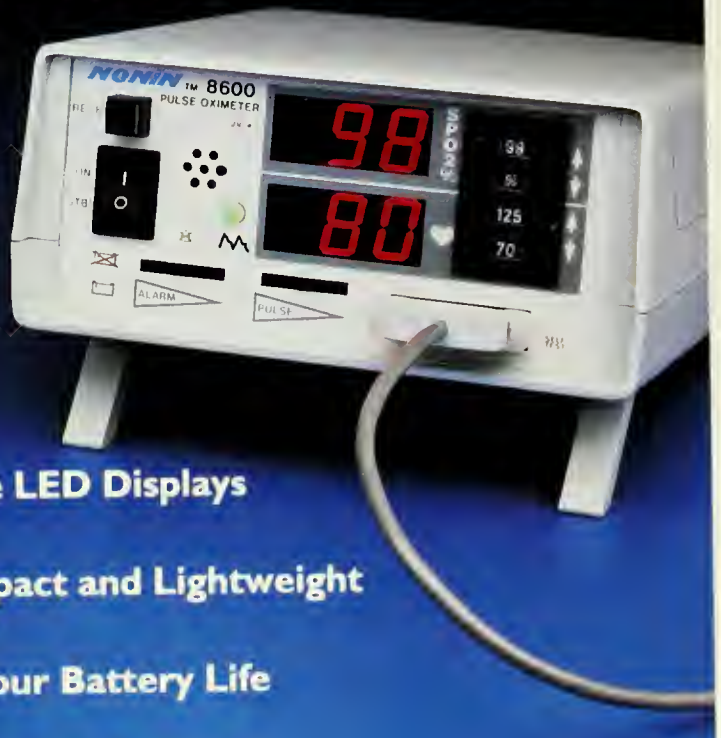

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Low levels of pressure support (PS) ventilation are commonly used to offset work of breathing (WOB) imposed by the ventilator, its circuit, and the ETT. Precise methods for determining desired PS level are not clear. Previous studies done by our group led us to suspect that certain PS levels may impose more work than the simple T-piece. We developed a protocol for bedside determination of WOB and inspiratory power normalized for tidal volume [P_I/V_T, where $P_I/V_T = (W_I)(RR)/V_T$ with W_I = inspiratory work] using the ALFA (Adult Lung Function Analyser, Medical Associated Services Inc). 5 studies were done on 4 ICU patients to compare P_I/V_T on T-piece at a flowrate of 45 L/min vs PS 5 cm H_2O, PS 10, and PS 15. Order of trial was random. All ventilators were set for sensitivity 0.5 cm H_2O. During a 3-min acquisition at each setting, ALFA continuously measured and recorded flow, proximal airway pressure, and airway pressure distal to ETT via Jet Swivel adapter (Portex Inc Cat. No. 600101). Breaths selected and manually verified were used by ALFA to compute P_I/V_T and minute ventilation ($\dot{V}_E$).

			Inspiratory Power/V_T, kg-cm · min·L^{-1}*			
Pt	Tube Size	$\dot{V}_E$	T-Piece	PS 5	PS 10	PS 15
	(mm)	(L/min)				
1a	6.0	9.9 (0.97)	161.0 (4.9)	87.7 (3.0)	87.3 (3.9)	68.4 (5.5)
1b	6.0	10.5 (0.18)	78.9 (2.5)	116.6 (3.1)	74.5 (3.5)	64.3 (2.5)
2	6.0	11.5 (0.21)	86.0 (8.2)	52.2 (2.1)	35.2 (3.0)	19.4 (1.5)
3	7.5	8.2 (0.40)	80.2 (6.6)	63.2 (10.4)	22.4 (3.5)	25.2 (6.3)
4	7.5	9.2 (0.14)	123.0 (2.8)	115.2 (5.7)	39.8 (1.7)	13.9 (1.90)

*Values are mean (SEM).

There are wide variations $\dot{V}_E$ in the WOB expressed as P_I/V_T in each weaning mode, with no intuitive relationship between tube size or $\dot{V}_E$ that allows the practitioner to predict desired PS level to offset T-piece. Variations are most likely due to individual patient's breathing pattern and synchrony with ventilator, suggesting importance of bedside analysis of P_I/V_T to optimize weaning modalities. (OF-92-193)

A Comparative Study of Respiratory Mechanics Parameters in Normal Individuals during Spontaneous, Bi-level Positive Airway Pressure (BiPAP), Pressure Support Ventilation (PSV), and Flow-By (FB) Ventilation—D Theron Van Hooser MEd RRT, James Bowman BA RRT, Les Winslett CRTT RPFT, Vencor Hospital-Denver, *Denver*; Kent Christopher RRT MD, Swedish Medical Center, *Englewood—Colorado.*

Introduction: BiPAP, PSV, & FB have been reported to improve ventilation in lung disease. We wished to determine whether differences exist in V_T, $\dot{V}_E$, f, R_{aw}, inspiratory work of breathing (WOB_I), pressure-time product (PTP), peak expiratory flowrate (PEFR), & respiratory drive (P_{100}) of normal individuals during spontaneous breathing (Spont) & PSV, BiPAP, & FB. **Method**: Using Bicore CP-100 respiratory monitor, $\dot{V}$, V, R_{aw}, and P_{es} were collected from 10 healthy nonsmoking volunteers. Except for Spont, order of breathing modes was randomized & unknown to volunteer (devices were concealed with sound patterns obscured by operating all devices at same time). Binary data were collected for 200 seconds on each mode following an acclimatization period. BiPAP pressures of 15/5 were from new Respironics ST-D unit. PSV 15/5 & FB (base flow 5, sensitivity 2) from new Puritan-Bennett 7200ae ventilator. Hotelling's T^2 was used to examine differences in 4 modes. $p < 0.05$ considered significant. **Results**: Mean (p values) of comparisons to Spont are shown.

	V_T (mL)	$\dot{V}_E$ (L)	f	R_{aw} (cm/L/s)
Spont	569	5.92	11	4 107
BiPAP	944 (0.005)	14 4 (0.001)	15 (0.0068)	3.97 (0.852)
PSV	1136 (0.0003)	11.7 (0.0004)	11 (0.6755)	3.455 (0.2716)
FB	558 (0.7344)	6.44 (0.1383)	12 (0.1897)	3.59 (0.1834)
	WOB_I (j/L)	PTP (cm/H_2O/s)	PEFR (L/s)	P_{100} (cm H_2O)
Spont	0.601	151.23	0.302	1.22
BiPAP	0.147 (0.0004)	85.73 (0.0192)	0.732 (0.001)	0.835 (0.0255)
PSV	0.076 (0.0001)	35.4 (0.0002)	0.649 (0.0001)	1.399 (0.3284)
FB	0.476 (0.0023)	133.0 (0.1025)	0.281 (0.2712)	1.189 (0.8227)

FB reduces WOB_I, but is otherwise not different from spontaneous, PSV reduces WOB_I, V_T, $\dot{V}_E$, PTP, PEFR, while f, R_{aw}, & P_{100} are not different from Spont. Because of tendency of BiPAP to autocycle, rate & P_{100} were different from Spont, otherwise BiPAP had same effect as PSV. **Conclusions**: FB can reduce WOB_I of normal individuals without affecting the other variables. As expected, both BiPAP & PSV also reduce work, increase volumes, & lower inspiratory efforts (PTP) of normal individuals. P_{100} is affected by BiPAP because of tendency to autocycle. (OF-92-201)

The Chronic Adult Patient

Work of Breathing Imposed during Spontaneous Breathing in the SIMV Mode of Home Care Ventilators—Peggi Robart RRT, Chartwell Home Health Care, *Waltham;* Christopher Hirsch MPH RRT, Robert M Kacmarek PhD RRT, Sylvester Barker LPN, Massachusetts General Hospital, *Boston—Massachusetts.*

A previous report (Respir Care 1990;35:405) indicated that the imposed work of breathing (WOB_I) during the spontaneous breathing phase of SIMV with home care ventilators is excessive. To determine if improvements have been made over previous models, we evaluated the WOB_I by the newest home care ventilators: Aequitron LP-10, Puritan-Bennett 2801, and Lifecare PLV-102. **Methods**: All evaluations were performed on a spontaneous breathing lung model consisting of a Michigan Instruments TTL, powered by a Puritan-Bennett 7200 ventilator. Ventilators were set up according to manufacturers' directions, using a passover humidifier. Prior to attachment of each ventilator, the lung model was set to function at a rate of 20 breaths/min with each of the following V_Ts and peak inspiratory flows ($\dot{V}$, decelerating pattern) V_T 0.35 L, $\dot{V}$ 20 L/

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min; V_T 0.45 L, $\dot{V}$ 40 L/min; V_T 0.50 L, $\dot{V}$ 50 L/min. WOB_I and maximum negative inspiratory pressure (P_{max}) developed were measured with a Bicore CP-100 pulmonary monitor. **Results**: The following results were obtained at V_T 0.45 L, $\dot{V}$ 40 L/min settings. Each represents the mean (SD) of 5 breaths. Similar variations were found at the other V_T and $\dot{V}$ settings.

	LP-10	P-B 2801	PLV-102
WOB_I (joules/L)	0.1369 (0.0000)	0.1905 (0.0000)*	0.2673 (0.0001)*
P_{max} (cm H_2O)	−3.8726 (0.0017)	−5.0399 (0.0005)*	−8.3622 (0.0014)*

*$p < 0.01$ ANOVA vs LP-10.

Conclusions: Moderate to high levels of WOB_I and P_{max} were measured with all home care ventilators; however, these three demonstrate improvements over previous models, the LP-10 demonstrating the greatest improvement. (OF-92-102)

Comparison of Three Fixed-Orifice Devices for the Delivery of Positive Expiratory Pressure to Non-Intubated Patients—JA Lieberman MD, JL Tarnow RRT, NH Cohen MD. University of California Medical Center, *San Francisco, California.*

Positive expiratory pressure (PEP) therapy is used in non-intubated patients to improve lung volumes and facilitate clearance of bronchial secretions. PEP can be generated by a fixed-orifice expiratory flow resistor that mimics the effects of "purse-lipped" breathing. Three different devices on the market are capable of applying an expiratory resistance (Resistex, Ambu, and Astra) with multiple orifice sizes ranging from 1-5 mm in diameter. In our institution, orifice size is chosen to yield expiratory pressures of 10-20 cm H_2O and I:E of 1:3 to 1:4. We employed a mechanical lung model simulating a spontaneously breathing, passively exhaling patient to compare the effects on pulmonary mechanics of the 3 devices. For each device tested, we maintained constant inspired tidal volume, inspiratory flowrate and waveform, lung system compliance, and respiratory rate, while varying the size of the orifice. Measurements of airway flows and pressures were recorded using a Bicore CP-100 monitor. In addition, the Michigan TTL test lung yielded data for intrinsic PEEP and end-expiratory volume. Data presented are averages of values measured for 20 breaths in steady-state for 2 different orifice diameters. Variation from the mean was < 5% for all values shown.

Device	Orifice Size (mm)	PEFR* (L/s)	t_{exp} (s)	P_{paw} (cm H_2O)	WOB_I
Control	none	0.81	0.78	8	0.35
Resistex	3.8	0.56 (69)	2.0 (256)	18 (225	0.34 (97)
Ambu	4.0	0.61 (75)	1.9 (243)	18 (225)	0.33 (94)
Astra	4.0	0.60 (74)	1.8 (231)	18 (225	0.36 (103)
Resistex	2.1	0.27 (33)	4.8 (615)	22 (275)	0.34 (97)
Ambu	2.0	0.25 (31)	5.0 (640)	24 (300)	0.32 (91)
Astra	2.0	0.23 (28)	4.8 (615)	24 (300)	0.36 (103)

*PEFR = peak expiratory flowrate, t_{exp} = expiratory time, P_{paw} = peak expiratory airway pressure.

All 3 fixed-orifice valves comparably limited peak expiratory flows and prolonged expiratory time in proportion to the size of valve orifice, with no significant differences in effect on P_{paw}. No valve caused air-trapping or led to intrinsic PEEP; the FRC of the mechanical lung returned to baseline at end-expiration. None of the devices imposed any additional inspiratory work of breathing, as measured by the area under a pressure-volume loop during inspiration (WOB_I). In conclusion, PEP provided by these devices was affected solely by chosen orifice size and not by the brand of valve. The Ambu and the Astra systems offer a greater variety of orifice diameters; the Resistex device is less expensive. When selecting equipment for administration of PEP therapy, the clinician must carefully consider both the goals and the cost-effectiveness of the therapy. (OF-92-023)

Support at Home: A Program for Oxygen-Dependent Homebound Patients—Patricia O Baker MSN RRT. American Lung Association of Virginia, *Virginia Beach, Virginia.*

The increasing prevalence of chronic lung disease is leading to an increasing number of people who require continuous oxygen therapy in the home. Chronic illness often results in the feeling of loss of control and powerlessness, loss of self-esteem, inadequate coping, and possible depression. Miller (1983) proposed a framework for patient empowerment based on coping strategies used when resources are compromised. This model was used as the basis for the development of a program to provide support for homebound patients and their family members, thus enhancing their psychological well-being. A pilot program was conducted in which a group of volunteers were trained in communication skills after which they provided 9 visits to 10 selected patients. They provided educational materials, information about community resources, companionship, and support. The purpose of the pilot study was to determine the relationship between level of social support and level of psychological well-being. A single group, pre-test:post-test, quasi-experimental design was used to evaluate the effectiveness of the program. Research questions included (1) Is there a relationship between level of satisfaction with social support and psychological well-being; (2) would psychological well-being increase as a result of the program; and (3) what were the benefits derived from the program by the participants. There was a positive correlation between level of satisfaction with social support and psychological well-being, $r = 0.77$. There was no significant increase in psychological well-being as measured by the pre-test:post-test surveys. This may be due to the small sample or to the instruments used. However, data from the program evaluations, which included open-ended questions, indicate that the program did have positive effects. Nine of the 10 patients indicated that the program gave them something to look forward to and all of the patients indicated that it lifted their spirits, it made them feel better, and they would recommend it to others. The program will be continued and further research will be done on its effects. (OF-92-026)

Physiological and Psychological Effects of Low-Impact Aerobic Exercise on Young Adults with Cystic Fibrosis—Crystal L Dunlevy EdD RRT, F Herbert Douce MS RRT, Ohio State University; Ellen Hill MS RCPT RRT, Steven Baez MD, Riverside Methodist Hospitals—*Columbus, Ohio.*

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Obstructive lung disease is a common occurrence in the U.S. Patients afflicted with asthma, cystic fibrosis, chronic bronchitis, or emphysema are generally debilitated as a result of increased secretions, mucociliary clearance impairment, and frequent infections. Further, these patients typically suffer from increased anxiety and depression related to their physical state. Evidence exists to support the claim that exercise can improve work capacity and oxygen uptake in these patients, as well as alleviate the associated emotional problems of depression and social isolation that they commonly experience. The purpose of the study was to determine the effect of a structured low-impact aerobic exercise program on the patients' work capacity, oxygen uptake, and reported quality of life. Ten subjects between the ages of 19 and 31 with mild-to-moderate cystic fibrosis began the study; six completed it. Identification of mild-to-moderate disease was made by physician diagnosis and pulmonary function testing results (FEV_1 % predicted, FEV_1/FVC). Subjects had no other restrictive or obstructive lung disease, no cardiac disease, were not currently exercising, and were nonsmokers. Spirometry and exercise testing were performed on all subjects before and after participating in an 8-week low-impact aerobic exercise program. Participants also completed the Bush Quality of Well-Being (QWB) Scale, which is a measure of perceived quality of life before and after the exercise component. Subjects participated in an 8-week low-impact aerobic exercise program consisting of one 30-minute session of aerobic walking and two 30-minute sessions of low-impact aerobic dance/week. Pre- and posttest forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), forced expiratory flow (FEF_{25-75}), resting heart rate, work load, oxygen uptake, and QWB scores were compared for each subject. Two-tailed *t* tests were applied, with $p \leq 0.05$ considered to be statistically significant.

Measurements of Spirometry, Exercise, and QWB Before and After an 8-Wk Program of Low-Impact Aerobic Exercise

	Pre-Exercise*	Post-Exercise*	p Value
FVC % pred	77.8 (10)	75.7 (11.3)	0.12
FEV_1 % pred	58.2 (7.8)	55.8 (8.6)	0.31
FEF_{25-75} % pred	24.7 (8.4)	23.2* (5.1)	0.59
Peak VO_2 mL/kg/min	35.73 (4.91)	43.57 (7.66)	0.005
METS	10.3 (2.2)	12.8 (3.1)	0.0052
Resting HR, bpm	96 (14.1)	82 (15)	0.0052
QWB	0.74 (0.09)	0.74 (0.02)	1

*Values are mean (SD).

There was no significant difference in FVC, FEV_1, FEF_{25-75}, or QWB ($p > 0.05$). Subjects showed significant improvement in the following parameters: maximal oxygen consumption ($p = 0.006$); work load, measured in metabolic equivalents ($p = 0.016$); and resting heart rate ($p = 0.003$). Findings suggest that low-impact aerobic exercise significantly improves ability to utilize oxygen and decrease myocardial work in patients with mild-to-moderate cystic fibrosis. (OF-92-034)

Pulmonary Function Response to Albuterol MDI in Stable COPD Patients: A Comparison of FVC, FEV_1, SVC, and PF—Michael T Kochansky RPFT, Laura Acosta, York Hospital, *York, Pennsylvania.*

A common method used to assess response to bedside administration of inhaled bronchodilators is measurement of peak flow (PF) before and after treatment. FEV_1, FVC, and SVC are measured less frequently at the bedside. PF is often performed on all hospitalized patients receiving bronchodilator therapy, including both asthmatic and COPD patients. The purpose of this study was to compare PF, FEV_1, FVC, and SVC responses following inhaled bronchodilator in stable COPD patients. **Methods:** Pulmonary function tests of 62 stable non-asthmatic COPD patients who completed our 6-week Outpatient Pulmonary Rehabilitation Program were evaluated for changes in pulmonary function. An improvement ≥ 15% in any value was considered a positive response. Testing was performed under laboratory conditions using a Keystone computerized lung analyzer (S & M Instrument Co). Two puffs of therapist-administered albuterol via MDI and InspirEase were used as the bronchodilating agent. All calibration, equipment, and testing procedures exceeded ATS standards for spirometry. Sensitivity and specificity were used for comparison of parameters. **Results**: The proportion of positive responses in FVC, FEV_1, SVC, and PF were 65%, 53%, 35%, and 35%, respectively. The parameter with the best improvement was FVC in 25 patients (40%), followed by FEV_1 for 13 patients (21%), SVC for 9 patients (15%), and PF for only 7 patients (11%). No improvement was found in any parameter for 8 patients (13%). Peak flow measurements were insensitive identifiers of those with significant improvement in FVC (sensitivity = 43%, false-negative rate = 57%) and in FEV_1 (sensitivity = 46%, false-negative rate = 54%). However, a PF value with < 15% improvement was better at identifying insignificant changes in FVC (specificity = 85%, false-positive rate = 15%), and FEV_1 (specificity = 88%, false-positive rate = 12%). **Conclusions**: Our data suggest that PF for bedside assessment of response to inhaled bronchodilator should be used with caution in non-asthmatic COPD patients. FVC and FEV_1 are better indicators of response to bronchodilator. COPD patients may be more likely to have a reduction in air-trapping following bronchodilator administration, reflected by an increase in FVC, and often have little or no change in PF. (OF-92-052)

Predictive Value of Pulmonary Function Tests for Exercise-Induced Hypoxemia in Chronic Obstructive Airway Disease—Brent VanHoozen MD, UC Davis Medical Center, *Sacramento, California;* Susan Blonshine RPFT RRT, Robert E Klimek MD, John Siano MD, Ingham Medical Center, *Lansing, Michigan.*

Introduction: Pulmonary function studies have often been used by physicians to screen patients with COPD for exercise-induced hypoxemia. A number of studies have evaluated the predictive value of parameters such as FEV_1, FEV_1/FVC%, and D_{LCO} in predicting hypoxemia with exercise, with varying

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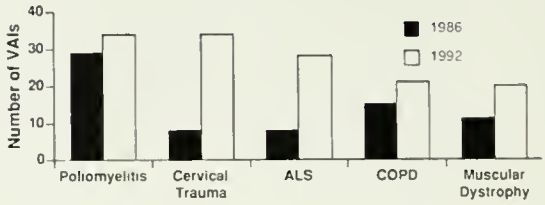
results. Recent studies suggest that D_{LCO} and $FEV_1/FVC\%$ may not have adequate sensitivity to predict hypoxemia with exercise in COPD. The purpose of this study was to evaluate the predictive value of FEV_1, $FEV_1/FVC\%$, and D_{LCO} for exercise-induced desaturation. **Method**: A retrospective chart review of 180 patients who had performed pulse oximetry with exercise, spirometry, and D_{LCO} yielded 79 charts that met the inclusion criteria for COPD. All test battery components for a given patient had been completed within 1 month. No methodologic or equipment changes had occurred over the study period. Results were excluded if patients did not reach peak heart rate or if other medical conditions precluded completion. Our procedure is to validate pulse oximetry by blood gas analysis prior to beginning the exercise study. Smoking history and associated increased carboxyhemoglobin levels were noted. Using exercise pulse oximetry as the standard for detecting exercise-induced hypoxemia, the relative sensitivity, specificity, and predictive values of the spirometric and diffusion studies were calculated. **Results**: The sensitivity of an $FEV_1 < 1.1$ L for predicting exercise desaturation was 72% and specificity was 63%. Positive and negative predictive values were 70% and 65%, respectively. Sensitivity and specificity for a $FEV_1/FVC\% < 50\%$ were 77% and 51%. Positive and negative predictive values were 50% and 76%. Using the receiver-operating-characteristic (ROC) curve technique, the FEV_1, $FEV_1/FVC\%$, and D_{LCO} were evaluated for highest combined specificity and sensitivity. ROC curve analysis revealed that an FEV_1 of 1.4 L had best combined sensitivity and specificity, 91% and 57%, respectively. Further data analysis revealed that an $FEV_1 > 2$ L had a negative predictive value of 100%. **Conclusion**: This study demonstrated that pulmonary function variables evaluated were not particularly sensitive in predicting exercise-induced hypoxemia. However, they may be useful in excluding exercise hypoxemia in subjects with less severe impairment. (OF-92-065)

Surveys of Long-Term Ventilatory Support in Minnesota: 1986 and 1992—Alexander B Adams MPH RRT, Theodore Marcy MD, St Paul-Ramsey Medical Center; Judy Whitman RRT, HealthEast—*St Paul, Minnesota.*

The actual number of ventilator-assisted individuals (VAI) in the United States is largely unknown, and a system to track this information (eg, a registry) does not exist. This information would be useful in developing programs to provide support services and in forecasting the economic costs of this intervention. **Methods**: To determine the prevalence and some characteristics of VAIs in Minnesota, we conducted surveys of this population in Minnesota in 1986 and 1992 by canvassing long-term care units and home medical equipment providers. **Results**: The number of VAIs in 1992 was 110% greater than in 1986 (216 vs 103). In 1986, 81% of these patients received care at home; the remaining patients were supported in long-term care facilities. By 1992, the percentage had changed to 65% supported in the home and 35% in long-term care facilities. Diagnostic categories and numbers of VAI are shown. Diagnoses with the greatest increases in number of patients were cervical trauma and ALS.



When VAIs were categorized by age groups, a large increase in proportion of patients < 10 years of age and > 60 years of age was revealed. **Conclusion**: If we assume a uniform distribution of VAIs across entire population of the U.S., our surveys suggest that number of VAIs in U.S. increased from 5,777 in 1986 to 12,279 in 1992. Although number of patients is small, total resources required for care of these patients can be substantial. These data suggest that we need to monitor number and demographic characteristics of VAIs in U.S. so that appropriate policies and programs can be developed to provide effective support services. (OF-92-122)

Abdominal Binders: Effects of Vital Capacity in Quadriplegic Patients—Karen S Whitesell BS RPT, Joseph P Lynott BS RRT, Christy M Bruns BS, Julie Parker BS, Denise T Wagner BS, National Rehabilitation Hospital, *Washington, District of Columbia.*

The purpose of this study was to measure the effect of using an elastic abdominal binder on the vital capacity (VC) of quadriplegic patients. Although the reduced respiratory function in quadriplegia has been well documented, and elastic abdominal binders are commonly used in acute quadriplegic management, we have found no study that reports the effect of these abdominal binders on respiratory function. Our hypothesis was that VC would be greatest in a sitting position while wearing an abdominal binder. We measured the VC of 20 motorcomplete quadriplegic patients (C-4 to C-7) under four circumstances: sitting without an abdominal binder; sitting wearing an abdominal binder; supine without an abdominal binder; and supine wearing an abdominal binder. We controlled for active respiratory disease, thoracic orthopedic deformity, stomach and bowel distention, and placement of the binder. In 19 of 20 subjects, mean VC was greatest wearing the binder regardless of supine or sitting position (2.44 vs 2.22, respectively). In 19 of 20 subjects, mean VC while sitting wearing the binder was greater than mean VC sitting without the binder (2.22 vs 1.90, respectively). The lowest VC was in sitting without the binder in 18 of 20 subjects (1.90); mean VC without binder in supine position was 2.29. Paired *t* tests supported our hypothesis. We conclude that the use of abdominal binders improves VC in acute and chronic quadriplegia. (OF-92-158)

Topics in Education

Assessing the Effectiveness of Observation Training for Clinical Instructors—David L Collins MS RRT, Thomas V Hill MS RRT, Kettering College of Medical Arts, *Kettering*; Peggy Leahy PhD, University of Dayton, *Dayton—Ohio.*

Introduction: Many respiratory care programs rely heavily on observation instruments to assess student performance in the clinical setting. In addition, the practice of utilizing volunteer clinical instructors (CI) to assess student performance is commonplace. The combination of these variables raises questions about the reliability of this method of multi-observer assessment. The purpose of this study was to determine whether a training program using videotapes prepares CI to accurately record clinical performance on checklist instruments as measured by an interobserver agreement percentage of ≥ 0.85. METHODS: Using a randomized control-group post-test-only design, CI were assigned to a control group (n = 17) or a comparison group (n = 17). The CI in the comparison group attended a training session during which they viewed segments of videotapes showing tracheal aspiration (TA) and chest physiotherapy (CPT) performed according to commonly accepted standards of care. The videotapes were developed by the AARC for use by supervisory personnel responsible for evaluating clinical performance. Comparison-group CI reviewed checklist instruments and procedural specifications for TA and CPT that corresponded to the videotapes. The dichotomously scored checklist instruments identified tasks essential to correct performance of TA and CPT. The instruments were developed by the investigators and piloted by an expert panel to establish interrater reliability and face and content validity. One week later, both groups attended a post-test session during which segments of the TA and CPT videotapes with incorrectly performed or omitted tasks were shown. The CI completed the checklist instruments while viewing the videotapes. **Results**: Data were statistically analyzed using 1-tailed *t* tests for independent samples. The level of significance was set at 0.05. The interobserver agreement percentage was greater for comparison group than control group for both TA (0.885 vs 0.672) and CPT (0.926 vs 0.680), and the difference was significant for both procedures ($p < 0.001$). Calculation of effect size demonstrated practical significance. **Conclusion**: The comparison group was more accurate in using the checklist instruments to record clinical performance shown in the videotapes. Educators may consider developing similarly designed training programs for preparing CI to use checklist instruments to evaluate clinical performance. (OF-92-125)

Structure-to-Function Relationships and the Determination of Diffusion Capacity in Chicken Eggs: An Accessible Project for Students—Kenneth D McCarty MS RRT, Hoai N Tran CRTT, Robert W Patterson RRT, A Bradley Jones CRTT, John M Takaki, Loma Linda University, *Loma Linda;* DE Bebout PhD RRT, Stephen C Hempleman PhD, UC-San Diego, *San Diego—California.*

Introduction: Identifying research projects that are both accessible and suitable for respiratory therapy students is often difficult. Cost, equipment, supplies, patient availability, and approval of protocols are only some of the hurdles that must be overcome. We describe an original research project carried out by respiratory therapy students that is accessible, requires minimal resources, and provides students with hands-on research experience. The bird egg is a self-contained life support system that supplies everything necessary for the developing embryo except O_2. O_2 and CO_2 are exchanged by simple diffusion through microscopic pores in the otherwise impermeable eggshell. This process is described by Fick's first law of diffusion and is thus regulated largely by shell thickness and pore geometry. The purpose of this study was to identify two groups of eggs with functionally different diffusing capacities, and then to determine the structural differences in the eggshells that were responsible for the variation in diffusive conductances. **Method**: 24 Grade AA infertile chicken eggs were numbered, weighed, and placed in a desiccator for 1 week. The eggs were then reweighed and H_2O vapor conductance [GH_2O; mg/(d · torr), an estimate of diffusing capacity] was calculated by gravimetric method. Only the eggs with the 6 highest and 6 lowest GH_2O were studied further. 5 samples were taken from each egg and shell thickness (L, mm) was measured with a micrometer. Aggregate pore area (Ap, mm^2) was then calculated by Fick's first law of diffusion: $GH_2O = (Ap/L) \cdot (D/RT)$, where D is the binary diffusion constant for H_2O in mm^2/d, R is the respiratory gas constant in $(mm^3 \cdot torr)/(mg \cdot K)$, and T is temperature in K. Shell samples were etched in HNO_3 and stained with methylene blue dye, and pore number (N, mm/cm^2) was then determined by microscopy and average pore radius (r, μm) calculated. **Results**: Mean (SD) GH_2O was 18.1 (2.0) mg/(d · torr) in the high group compared to 9.8 (0.5) mg/(d · torr) in the low group ($p < 0.005$). Shell thickness was not different between groups and was 0.344 (0.017) and 0.361 (0.017) mm in high and low groups, respectively. Mean Ap was > in high group and was 2.91 (0.16) mm^2 compared to 1.66 (0.12) mm^2 in the low group ($p < 0.005$). Both N and r were greater in the high group and were 94 (12) pores/cm^2 and 11.8 (0.611) µm compared to 70 (6) pores/cm^2 and 10.1 (0.6) μm ($p < 0.05$). **Conclusions**: We conclude that the functional difference in diffusing capacity between these two groups of eggs is best explained by structural differences in pore number and size, and not by differences in shell thickness. This study was performed in one academic quarter as the final project in a 3-class series on respiratory care research, and provided students with hands-on experience in applying Fick's first law of diffusion to determine structure-function relationships in a simple biological model of diffusing capacity, the chicken egg. (OF-92-140)

New Techniques and Devices

Surfactant Replacement following Wood Smoke Exposure In Vitro—Gary F Nieman BA, SUNY Health Science Center, *Syracuse, New York.*

Introduction: Indirect evidence indicates that a major component of smoke inhalation (SI) pathophysiology is pulmonary surfactant (PS) deactivation (Respir Care 1991;36:1211). Although the pathologic changes following SI (ie, lung collapse, increased shunt, and decreased lung compliance) suggest PS destruction, the direct effect of smoke on PS has not been measured. Furthermore, if smoke inhibits PS, the possibility

exists that PS replacement therapy (PSRT) may be an effective treatment for severe SI. **Methods**: 10 dogs were sacrificed and PS harvested from lung lobes (right and left apical, cardiac, and diaphragmatic lobes) by saline lavage. Lung lobes were surgically separated, and the main airway to each lobe isolated. Saline (60 mL) was slowly injected into (5 times), and then withdrawn from, each lobe. This process was repeated 3 times (180 mL saline total) and the extract placed in the Teflon trough of a Modified Wilhelmy Balance (WHB). Surface tension (ST) was continuously recorded (Gould UC3 transducer and Hewlett-Packard 7754 amplifier and strip recorder) as the WHB trough was changed from a 100% (ST max) to 20% (ST min) surface area. A baseline ST/trough area curve (S/A) was generated with PS function considered normal if ST min was < 10 dynes/cm. Smoke was generated in a Harvard animal ventilator modified to produce smoke; the fuel source was a mixture of fir plywood sawdust moistened with kerosene. The sawdust was ignited in the ventilator and smoke was blown into a 4-L bottle. Our laboratory has used this method of generating smoke as a model of severe SI for > 10 years (Surgery 1980;191:171). **Protocol:** Following establishment of a normal S/A curve, a 4-L dose of smoke was blown over the surface of the WHB trough. ST data were collected immediately following smoke exposure. A second dose of PS lavage extract (PSRT) was added to the WHB following smoke exposure and ST data again collected. **Results**: Data shown are mean (SEM).

	Normal	Smoke	PS Replacement
ST min value (dynes/cm)			
Mean (SEM)	6.1 (0.3)	22 (1.6)*	9.4 (2.6)

*$p < 0.05$ vs both normal and PS replacement.

Conclusion: Smoke inhibits PS function, explaining the pathologic effects of SI seen in vivo; however, PS function can be restored by replacing surfactant. These data suggest that pulmonary surfactant replacement therapy may be beneficial in the treatment of patients with severe smoke inhalation. (OF-92-038)

Exosurf Aerosol Treatment of Severe Wood Smoke Inhalation—Robert R Fluck Jr MS RRT, Gary F Nieman BA, Andrew M Paskanik, William R Clark Jr MD, Tawfic S Hakim PhD. SUNY Health Science Center at Syracuse, *Syracuse, New York.*

Introduction: Smoke inhalation (SI) causes a protein-rich pulmonary edema, and plasma proteins are known to inhibit pulmonary surfactant (PS). Smoke also directly deactivates PS (Respir Care 1991;36:1211). Therefore we attempted to treat SI with the artificial surfactant Exosurf administered according to manufacturer's directions. **Methods**: Mongrel dogs (n = 12) were anesthetized, placed on a Bear 5 ventilator (40% O_2), and surgically prepared for hemodynamic (systemic, pulmonary, and pulmonary artery wedge pressures) and cardiac output (Edwards Cardiac output computer) measurements. Arterial and mixed-venous blood gases and carboxyhemoglobin (COHb, %) were measured (Radiometer ABL-2; OSM-2 Hemoximeter, respectively); pulmonary shunt (%) and static compliance (SC, mL/cm H_2O) were calculated. At the conclusion of the experiment, lung samples were taken for morphometric, lung water (wet-dry wt ratio, W/D), and dynamic surface tension (ST, as measured by Modified Wilhelmy Balance) analysis. Vascular permeability was assessed by injecting Evans blue dye (binds and color tags albumin) before smoke and measuring the color intensity of the perivascular edema cuffs in the morphometric samples. **Protocol**: Following baseline measurements, the animals were taken off of the Bear 5 and placed on a Harvard animal ventilator modified to generate smoke. Smoke was produced by burning a mixture of fir plywood sawdust moistened with kerosene and delivered with tidal ventilation for 5 min at a respiratory rate of 26 breaths/min. Following SI, the animals were returned to the Bear 5 and received either aerosolized normal saline (Control, C, n = 6) or Exosurf (E, n = 6) via VISAN VN-8 (Vortran Medical Technology Inc) for 4 hours at which time the animals were sacrificed. **Results:** Data are mean (SEM).

	Time (min)							
	Baseline		30		180		240	
	C	E	C	E	C	E	C	E
P_{aO_2}	214 (6)	220 (1)	66 (9)*	97 (17)*	91 (17)*	103 (25)*	85 (17)*	83 (21)*
COHb	0.3 (0.1)	0.5 (0.1)	35 (3)*	40 (3)*	15 (2)*	19 (2)*	10 (2)*	13 (3)*
SC	56 (3)	51 (6)	48 (4)*	44 (4)*	42 (5)*	35 (3)*	42 (5)*	35 (3)*

*$p < 0.05$ vs baseline, no significant difference between groups.

Smoke increased lung water [C 7.3 (0.3); E 6.9 (0.4), W/D], ST, and edema cuff color (ie, vascular permeability) above historic normal values. None of these pathologic changes were ameliorated by Exosurf treatment. **Conclusion**: SI deactivates surfactant effecting a decrease in P_{aO_2} and SC and increases vascular permeability resulting in pulmonary edema. Exosurf is ineffective in treating smoke inhalation pathophysiology, although other surfactants (Survanta or Infasurf) may be effective in SI treatment. Study supported by the American Respiratory Care Foundation. (OF-92-39)

Nitric Oxide Delivery System for Volume Ventilators—John Newhart RCP CRTT, F Wayne Johnson RCP RCPT CRTT, Ron G Konopka, Richard N Channick MD. UCSD Medical Center, *San Diego, California.*

Introduction: We have developed a generic system for delivering nitric oxide (NO) to intubated mechanically ventilated subjects for inhalation. Administration of NO as a potent vasodilator to spontaneously breathing subjects has been described in the literature (Circulation 1991;83:2038). **Method**: Our system was used with prior institutional review committee approval in an anesthetized animal model. Nitric oxide (EPA Protocol 1 ± 1%, 500 ppm) and balance nitrogen (N_2) were blended with ultra pure nitrogen via a 3800 blender (Bird Corp, Palm Springs CA). Blender output is connected to air input of the ventilator. The NO-N_2 mixture is mixed with oxygen (O_2) inside the ventilator via the internal air-oxygen blender and delivered to the subject as NO-N_2-O_2. Expired gas is col-

lected via an air capacitor connected to wall vacuum. To achieve the precise NO-N_2-O_2 mixture requires adjustment of the external 3800 blender and ventilator F_{IO_2} control. Separate calibration tables were developed to control NO-N_2-O_2 concentration. An online 8840 chemoluminescence analyzer (Monitor Labs/Lear Siglear, Englewood CO) is used to measure concentrations of inspired and expired NO and nitrogen dioxide (NO_2) continuously. On the inspiratory side, a pneumatic capacitor is placed between the analyzer sample line and ventilator to eliminate the effects of inspiratory circuit pressure. **Results**: Desired concentrations of NO, N_2, and O_2 are delivered to the subjects without exceeding OSHA Environmental Standards for NO and NO_2 (time-weighted average 25 ppm /8 h NO, 1 ppm/8 h NO_2).

Settings for Ventilator and 3800 Blender for Delivery of NO + O_2 Using 500 ppm NO + Ultra Pure N_2 + O_2 As Source Gases

		External Blender Settings for NO Delivery of NO-N_2 to Ventilator	
Delivered FO_2	Ventilator-Set FO_2	40 ppm NO	80 ppm NO
0.22	0.40	29	38
0.35	0.50	30	40
0.49	0.60	34	47
0.63	0.70	41	59
0.76	0.80	48	74
0.89	0.90	81	60 ppm max
0.96	0.95	30 ppm max	not applicable

Conclusion: 40 and 80 ppm of NO can be effectively delivered, continuously analyzed, and safely scavenged during mechanical ventilation. With this system and a 500 ppm NO source, a maximum F_{IO_2} of 0.89 at 40 ppm and 0.76 for 80 ppm can be delivered. A higher F_{IO_2} would necessitate a higher concentration NO source gas. (OF-92-057)

A Nebulizer System for Administering Synthetic Surfactant—Carl F Haas MLS RRT, Linda M Folk RRT, John G Weg MD, University of Michigan Medical Center, *Ann Arbor, Michigan;* David S Zaccardelli PharmD, D Les Brown PhD, Burroughs Wellcome Co, *Research Triangle Park, North Carolina.* (Study supported by Burroughs Wellcome.)

Introduction: Nebulized synthetic surfactant (SS) is being clinically investigated for the treatment of ARDS. A dense SS aerosol can occlude the expiratory filter of a ventilator system, causing a potentially harmful level of resistance to exhalation. A nebulizer system was developed (VISAN-9, Vortran Medical Technology Inc, Sacramento CA) to deliver a preset volume of aerosol into the inspiratory limb of the ventilator circuit during early expiration. To improve safety, the nebulizer system monitors the pressure drop across an exhalation aerosol filter and when it exceeds the equivalent of 4 cm H_2O at 100 L/min, the nebulizer alarms and turns off. **Study Objectives**: (1) to quantify the volume and rate of nebulization, and (2) to determine the accuracy and dependability of the filter's resistance monitor and alarm. **Method:** The nebulizer system interfaced to a ventilator (7200a, Puritan-Bennett Corp, Carlsbad CA) connected to a rubber lung model and set to V_T = 0.75 L; RR = 20/min; flowrate = 60 L/min; PEEP = 10 cm H_2O; and F_{IO_2} = 0.5. The nebulizer was set at 50°C to deliver a 0.6-L aerosol volume/breath. A developmental exhalation aerosol filter (DAF) (#SP1P782E1, Millipore Corp, Bedford MA) was placed proximal to the inlet of the ventilator expiratory filter (SPU, Puritan-Bennett). 16 DAFs were exposed to aerosol until the nebulizer system alarmed. Pre- and poststudy resistance measurements at 100 L/min were performed on each DAF. Nebulizer canisters (TriNEB-400, Vortran Medical Technology Inc) were each filled with 240 mL of SS (Exosurf, Burroughs Wellcome Co) and changed every 6 hours. Pre- and poststudy weight was obtained for each canister and DAF. The canisters were also weighed at 4.0, 4.5, 5.0, and 5.5 hours of nebulization. **Results:** Mean (SD) DAF pressure drop at alarm was 4.5 (1.5) cm H_2O (range 3-9 cm H_2O). Nebulization of 41.5 (4.6) g/h resulted in 97% of the drug's being nebulized by 6 hours. At 4.0, 4.5, 5.0, and 5.5 hours, 69%, 77%, 85%, and 92%, respectively, of the total drug had been nebulized. At 5.5 hours, 6 of 40 (15%) and at 6 hours 21 of 40 (53%) of the canisters had nebulized ≥ 99% of the drug. **Experience**: The nebulizer system efficiently aerosolized the SS over 6 hours. More than 360 hours of laboratory experience with the nebulizer system has shown it to alarm at the desired filter resistance. **Conclusion**: The nebulizer proved to be a safe and efficient device to produce dense aerosols, such as SS, during mechanical ventilation. (OF-92-092)

A Developmental Exhalation Aerosol Filter for Synthetic Surfactant during Mechanical Ventilation—Carl F Haas MLS RRT, Sherry J Johnson RRT, John G Weg MD, University of Michigan Medical Center, *Ann Arbor, Michigan;* David S Zaccardelli PharmD, Edward N Pattishall MD MPH, Burroughs Wellcome Co, *Research Triangle Park, North Carolina.* (Study supported by Burroughs Wellcome.)

Introduction: Dense aerosols, such as synthetic surfactant (SS), can occlude the expiratory filter increasing the risk of barotrauma and hemodynamic compromise when administered during mechanical ventilation. We tested a filter designed to prolong the ventilator filter (VF) life. **Objectives**: To determine the filter life of (1) an unprotected VF; (2) a developmental exhalation aerosol filter (DAF); and (3) a VF protected by a DAF. **Method**: A nebulizer system (VISAN-9, Vortran Medical Technology Inc, Sacramento CA) delivered aerosol into a ventilator circuit during expiration. The nebulizer system interfaced with a ventilator (7200a, Puritian-Bennett Corp, Carlsbad CA) connected to a rubber lung model and set to V_T = 0.75 L; RR = 20/min; flowrate = 60 L/min; PEEP = 10 cm H_2O; and F_{IO_2} = 0.5. The nebulizer delivered a 0.6-L aerosol volume/breath at 50°C. A DAF (#SP1P782E1, Millipore Corp, Bedford MA) was placed at the inlet of the VF (SPU, Puritan-Bennett). The nebulizer system monitored pressure drop across an expiratory filter—alarming and turning off if ≥ 4 cm H_2O at 100 L/min. Two studies were conducted with pressure sensors across an unprotected VF (VF-1), n = 2. Three studies were

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conducted with the sensors initially placed across the DAF (DAF-1), n = 3. At alarm, the DAF was changed and the sensors moved across the VF (VF-2), n = 3; subsequent (n = 8) unmonitored DAFs (DAF-2) were changed at the duration of the initial DAF or when mean airway pressure (MAP) rose by ≈ 2 cm H_2O. All studies were terminated when either the VF caused an alarm condition or at 48 hours. Nebulizer canisters contained 240 mL of SS (Exosurf, Burroughs Wellcome Co) at a concentration of 13.5 mg of dipalmitoylphosphatidylcholine/mL; canisters were changed every 6 hours. Pre- and poststudy filter weight and pressure drop measurements at 100 L/min were obtained. **Results**: Data are mean (SD).

		Pressure Drop (cm H_2O)		
Filter	Filter Life (h)	Pre	Post	Weight Gain (g)
VF-1	1.6 (0.8)	1.5 (0.7)	4.0 (1.4)	6.9 (4.7)
DAF-1	13.0 (1.9)	1.4 (0.4)	4.3 (0.6)	40.1 (3.3)
VF-2	48.0 (0.0)	1.1 (0.1)	2.6 (0.6)	5.6 (3.1)
DAF-2	10.9 (3.0)*	1.8 (0.2)	4.2 (0.9	32.2 (10.8

*2/8 had MAP increase = 2 cm H_2O at 5.7 and 6.8 hours

Conclusion: An unprotected VF lasted only 1.6 hours and the DAF 11-13 hours. The VF lasted at least 48 hours when the DAF was changed every 11-13 hours or with a pressure increase. (OF-92-093)

Performance of Prototype Portable HEPA-Filtered Positive Pressure Enclosures—Robert M Kacmarek PhD RRT, Joseph Kratohvil LPN RRT, Yuri Dashevsky MD, Ken Weinberg PhD, Ann Marie Kirkman BA MT, Cyrus Hopkins MD, Robert H Rubins MD, Massachusetts General Hospital, *Boston, Massachusetts.*

Development of pulmonary infection in immunosuppressed patients during hospitalization is a problem in many institutions. Positive-pressure HEPA-filtered patient isolation rooms and procedure areas minimize the risk. However, transport through hospital corridors may expose patients to multiple airborne organisms. We report on the ability of two prototype portable HEPA-filtered positive-pressure enclosures: Peace Medical (PM) and Viva-Tek Associates Inc (VT) to remove airborne organisms. **Methods:** Both units were placed in 10 different locations throughout the hospital and operated according to manufacturers' instructions for 2 hours at each location. During operation, continuous, simultaneous sampling of the environment inside and outside the enclosure was performed, using Anderson single-stage microbial particle samplers. Sixty cubic feet of gas/hour was drawn across petri dishes positioned within each Anderson sampler. All samples were sent to the hospital's Infection Control Laboratory for analysis. **Results**: No sample from inside either the PM or VT indicated any growth. However, all samples from outside both enclosures demonstrated heavy growth, with numerous bacterial and fungal species. Opportunistic pathogens (ie, *Candida albicans, Aspergillus fumigatus*) were identified in most areas sampled. **Conclusions**: Transport through hospital corridors does expose patients to numerous species of bacteria and fungi. The PM and VT prototypes of portable HEPA-filtered positive-pressure enclosures effectively eliminate airborne organisms from the internal environment of these enclosures. (OF-92-100)

Bronchoalveolar Lavage (BAL) Measurement of Pentamidine Lung Deposition—Kathy Kandal RRT, Christopher Brown MD, Michael Snow RPFT, Robert Fallat MD, California Pacific Medical Center, *San Francisco, California.*

Objectives: A Phase-II study was designed to compare the lung deposition of 300 mg of Pentamidine isethionate (P) delivered by the Respirgard II nebulizer (R) to P delivered by metered dose inhaler (MDI) using the high performance liquid chromatograph (HPLC) method to measure the drug in BAL fluid. An MDI that delivers 1.1 mg of P per activation has been developed. 7 subjects inhaled 300 mg of P delivered by R, and 14 inhaled 120 puffs of P from MDI. BAL was performed 24 h and 30 days after the initial dose. 7 of the MDI subjects inhaled 240 puffs of P from a MDI, and BAL was performed after 24 h. Subjects were men, HIV+, with CD4 counts > 400 mm^3, and with normal pulmonary function tests at baseline. **Methods**: BAL was performed by passing the bronchoscope into either the right middle lobe of lung for the 24-h or the left

lingula for the 30-day procedures. 6 aliquots of 30 mL of normal saline were instilled and aspirated manually to obtain samples. **Results**: Return of the samples was 68-147 mL, mean 122 mL. Qualitative cytology was done to verify source of the samples: Alveolar macrophages were the primary cell reported. BAL was centrifuged and P was measured in supernatant (S) and cell pellet (C). Concentration of P at 24 hours in S was mean (SD) 9 (4) ng/mL for 120 puffs; 25 (13) ng/mL for 240 puffs, and 17 (11) ng/mL for nebulizer. P in C was 11 (8) ng/mg for 120 puffs, 20 (6) ng/mg for 240 puffs, and 23 (19) ng/mg for nebulizer. At 28 days, P in S was 1.2 (0.8) ng/mL for 120 puffs and 2.9 (3) ng/mL for nebulizer. P in C was 4.5 (5) ng/mg for 120 puffs and 10 (12) ng/mg for nebulizer. The measurement of P showed correlation from 24 h to 30 days and 24 h after inhaling the 240 puffs ($r = 0.72$ and $r = 0.70$). **Conclusions**: Initially, we doubted that using BAL to determine lung levels of P would be reliable and reproducible. However, measurements of P in BAL revealed that the procedure could be reliably performed to obtain consistent samples for measurement of P. Adverse experiences were minor: 2 subjects had a slightly elevated temperature for < 12 hours, and 2 had nausea from the sedatives. BAL is a safe and reliable research technique for measurement of pentamidine deposition. (OF-92-130)

Pentamidine Delivered by Metered Dose Inhaler—Kathy Kandal RRT, Chuck Swanson MPA RCP RRT, Christopher Brown MD, Michael Snow RPFT, Robert Fallat MD. California Pacific Medical Center, *San Francisco, California.*

The FDA has approved 300 mg of Pentamidine isethionate (P) delivered by the Respirgard II nebulizer (R) for prophylaxis of *Pneumocystis carinii* pneumonia (PCP). Problems with therapy have included environmental contamination of P, resulting in hazardous exposure to health care workers, potential spread of TB, cost and inconvenience of therapy, and efficiency of the nebulizer. A metered dose inhaler (MDI) has been developed that delivers 1.1 mg of P with 0.25% of oleic acid and 98% Dichlorodifluoromethane of which 25% is in the respirable range of 1-5 μm. In a Phase-1 study, 30 male HIV+ subjects inhaled 126 puffs of P from MDI. Clinical laboratory results revealed no side effects. PFT showed 8/30 subjects had > 15% decrease in FEV_1 and 24/30 had > 25% decrease in FEF_{25-75}. All subjects completed dosing, but 2 subjects required albuterol. A Phase-2 study was designed to measure the level of P by bronchoalveolar lavage (BAL). 7 subjects inhaled 300 mg of P via Respirgard II, 7 inhaled 120 puffs of P from MDI, and 7 inhaled 120 puffs from MDI with spacer. BAL was performed at 24 h and 30 days post-dose. 7 subjects inhaled 240 puffs of P, and BAL P was measured after 24 h. Recovery of P in BAL from the nebulizer was between that found with 120 and 240 puffs from the MDI. Further studies are being conducted to investigate daily dosing of 8 and 24 puffs. The projected method of usage would be a daily dose of ≤ 24 puffs via MDI with a spacer device. Hazardous and infectious ambient aerosol would be reduced because of the use of a spacer, the smaller volume of aerosol, and the brief duration of dosing. The MDI could be taken independently, outside of the clinic setting. Therefore, the MDI may provide an efficacious, cost-effective, convenient method of delivering P to the lung and minimize, or even eliminate, environmental hazards. (OF-92-139)

Reversal of Hypoxic Pulmonary Vasoconstriction with Inhalation of Nitric Oxide during Mechanical Ventilation—F Wayne Johnson CRTT RPFT RCPT, John Newhart RCP CRTT, Ron G Konopka, Richard N Channick MD. UC-San Diego Medical Center, *San Diego, California.*

Introduction: In the evaluation and treatment of pulmonary hypertension, recent research has described the use of nitric oxide (NO) as a selective pulmonary vasodilator. NO has been reported as an endothelium-derived relaxing factor (EDRF) with the ability to relax vascular smooth muscle (Circulation 1991;83:2038). We examined ability of inhaled NO to reverse hypoxic pulmonary vasoconstriction (HPV) in mechanically ventilated subjects. **Method**: We developed a system for delivery of NO inhalation during mechanical ventilation. 6 canine models of HPV were used with prior institutional review committee approval. A Swan-Ganz thermodilution catheter (Baxter/Edwards) was placed in each subject. Hemodynamic measurements were made of pulmonary artery (PA), pulmonary artery wedge (PAW), right atrial (RA), and mean arterial (MAP) pressures. Cardiac output (QTD) was measured by cold-injectate thermodilution technique with a COM-2 (Baxter/Edwards, Santa Ana CA). Samples of arterial and mixed-venous blood were analyzed with a IL-1306 and IL-282 CO-OX (Instrumentation Labs). Derived calculations were made of pulmonary vascular resistance (PVR) and systemic vascular resistance (SVR). An external 3800 blender (Bird Corp) provided selected NO-N_2 mixtures. An 8840 analyzer (Lear Siglear) provided continuous analysis of NO and NO_2. Hemodynamic and ABG measurements were collected at test conditions of F_{IO_2} 0.50, F_{IO_2} 0.11, F_{IO_2} 0.11 with NO 40 ppm, and F_{IO_2} 0.11 with NO 80 ppm. Expired gas was collected via scavenger system connected to vacuum. **Results:** Data are mean (SD).

	Initial Baseline	Hypoxia Baseline	Hypoxia @ 40 ppm	Hypoxia @ 80 ppm
F_{IO_2}	0.50	0.11	0.11	0.11
PVR	207 (42)	502 (154)*	244 (52)†	227 (47)†
Q	2.9 (0.5)	4.6 (1.1)*	4.9 (1.3)*	4.7 (1.3)*
MAP	119 (16)	138 (26)*	128 (16)*	120 (15)†
P_aO_2	274 (8)	36 (3)*	35 (4)*	35 (4)*
$PaCO_2$	38 (2)	34 (2)	34 (1)	34 (2)
MetHb	0.8 (0.1)	0.8 (0.2)	0.9 (0.2)	0.1 (0.2)

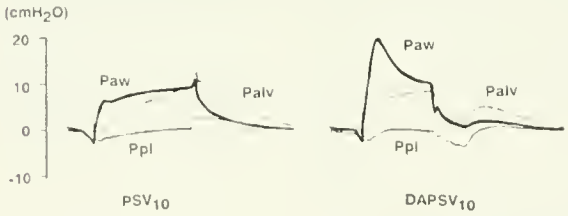
*$p < 0.05$ value differ from initial baseline.
†Value differs from hypoxic baseline

Conclusion: In canine subjects with HPV, PVR fell significantly after inhaled NO. No significant NO_2 or methemoglobin production was detected with short-term inhalation of NO. Monitoring NO_2 during the study showed < 1 ppm concentrations in inspired, expired, and ambient air. Our study demonstrated an effective and safe delivery system for use during mechanical ventilation. (OF-92-145)

Evaluation of Distal Airway Pressure Support Ventilation (DAPSV)—Toshimichi Takahashi MD, Yurii Konyukov MD, Jun Takezawa MD, Naoto Kuwayama MD, Toshiro Hotta RRT, Toshio Fukuoka RRT, Yasuhiro Shimada MD, Nagoya University Hospital, *Nagoya, Japan.*

Use of distal airway pressure (P_{daw}), instead of P_{aw}, as triggering and target pressure allows a new mode of mechanical ventilation called distal airway pressure support ventilation (DAPSV). Our study sought to validate this mode. **Method**: A spring-loaded bellows-type lung model was used to simulate spontaneous breathing. Diaphragm bellows was connected to jet-flow generator to generate inspiratory efforts. C_L and C_{cw} were 0.06 and 0.12 L/cm H_2O, respectively. RR was 20 breaths/min, & I:E 1:1. Puritan-Bennett 7200a ventilator was put in CPAP mode at PS level of 10 cm H_2O. ETT (ID 6.0, 7.0, & 8.0 mm) with embedded lumen in side wall was interposed between lung model & ventilator. Pressure monitoring line of ventilator was disconnected from expiratory limb and attached to pressure monitoring line of ETT. Expiratory (Exp) delay time, peak inspiratory P_{aw} (Insp P_{awp}), peak Exp Palv (Pavlp), and peak Exp Ppl (Pplp) were measured. **Results**: Pressure supporting time exceeded inspiration phase in PSV but prematurely terminated in DAPSV. At a matched V_T, DAPSV showed higher P_{aw} to attain set support level of P_{daw}. As a result, inspiratory negative deflection & expiratory overshooting of Ppl was minimized by DAPSV. This tendency is aggravated when smaller ETTs are used. **Conclusion**: Although DAPSV has a greater potential for improving synchrony than PSV, flow-termination criteria should be reduced to < 5 L/min for better patient-ventilator synchrony. (OF-92-203)

	PSV ETT ID (mm)			DAPS ETT ID (mm)		
	6	7	8	6	7	8
Insp P_{awp} (torr)	11	11	10	20	13	10
Exp delay (ms)	80	80	−160	−440	−400	−400
Exp Palvp (torr)	13	12	8	10	8	6
Exp Pplp (torr)	3	3	1	2	1	0



Continuous Nebulization of Albuterol Sulfate for Patients Experiencing Acute Airway Obstruction—Susan Rinaldo MEd RRT, Neil R MacIntyre MD, Duke University Medical Center, *Durham, North Carolina.*

Standard β_2-agonist aerosol therapy regimes may be inadequate during severe acute airway obstruction. To address this, we developed a protocol for adults to administer up to 40 mg/hour via a continuous nebulizer system (B & B Medical Technology Inc, Orangevale CA). We report, here, the results with our first 12 patients who received this protocol. **Method:** Continuous albuterol therapy (CAT) was administered to patients with severe refractory bronchospasm that persisted despite use of standard (up to q1h) administration of aerosolized β_2 agonists. Initial dosage was 10 mg/h and this dosage was increased in increments of 5 mg/h if the desired response was not obtained. Dosage was considered effective if the FEV_1 or peak flow increased by 15% and clinically important improvement in air movement was observed. Each dose was allowed to nebulize for at least 1 hour before the dosage could be increased. If at any time heart rate increased more than 20%, CAT was discontinued. Once the therapeutic end point was obtained, the patient was returned to a more standard dosing. **Results:**

	Duration CAT (h)	Max Dose (mg/h)	Patient Age	HR Change (%)	Peak Flow Change (%)	Respiratory Rate Change
Mean	2.5	16.25	44.4	11.0	73.2	18.3
Range	1.5	10-20	16-71	−10 to +51	15.4 to 285	−63.6 to +30

We terminated CAT after 1 hour in 1 patient due to an increase in heart rate > 20%. **Conclusions:** Use of increased dosages of albuterol sulfate appears safe and effective when nebulized continuously. Adverse effects such as increases in heart rate can be minimized when patients are monitored closely and a systematic approach is taken to determine whether higher dosages are indicated. A large randomized trial comparing CAT to standard regimens appears justified based on these results. (OF-92-015)

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beractant
intratracheal suspension

Sterile Suspension/For Intratracheal Use Only

INDICATIONS AND USAGE

SURVANTA is indicated for prevention and treatment ("rescue") of Respiratory Distress Syndrome (RDS) (hyaline membrane disease) in premature infants. SURVANTA significantly reduces the incidence of RDS, mortality due to RDS and air leak complications.

Prevention

In premature infants less than 1250 g birth weight or with evidence of surfactant deficiency, give SURVANTA as soon as possible, preferably within 15 minutes of birth.

Rescue

To treat infants with RDS confirmed by x-ray and requiring mechanical ventilation, give SURVANTA as soon as possible, preferably by 8 hours of age.

CONTRAINDICATIONS

None known.

WARNINGS

SURVANTA is intended for intratracheal use only.

SURVANTA CAN RAPIDLY AFFECT OXYGENATION AND LUNG COMPLIANCE. Therefore, its use should be restricted to a highly supervised clinical setting with immediate availability of clinicians experienced with intubation, ventilator management, and general care of premature infants. Infants receiving SURVANTA should be frequently monitored with arterial or transcutaneous measurement of systemic oxygen and carbon dioxide.

DURING THE DOSING PROCEDURE, TRANSIENT EPISODES OF BRADYCARDIA AND DECREASED OXYGEN SATURATION HAVE BEEN REPORTED. If these occur, stop the dosing procedure and initiate appropriate measures to alleviate the condition. After stabilization, resume the dosing procedure.

PRECAUTIONS

General

Rales and moist breath sounds can occur transiently after administration. Endotracheal suctioning or other remedial action is not necessary unless clear-cut signs of airway obstruction are present.

Increased probability of post-treatment nosocomial sepsis in SURVANTA-treated infants was observed in the controlled clinical trials (Table 3). The increased risk for sepsis among SURVANTA-treated infants was not associated with increased mortality among these infants. The causative organisms were similar in treated and control infants. There was no significant difference between groups in the rate of post-treatment infections other than sepsis.

Use of SURVANTA in infants less than 600 g birth weight or greater than 1750 g birth weight has not been evaluated in controlled trials. There is no controlled experience with use of SURVANTA in conjunction with experimental therapies for RDS (eg, high-frequency ventilation or extracorporeal membrane oxygenation).

No information is available on the effects of doses other than 100 mg phospholipids/kg, more than four doses, dosing more frequently than every 6 hours, or administration after 48 hours of age.

Carcinogenesis, Mutagenesis, Impairment of Fertility

Reproduction studies in animals have not been completed. Mutagenicity studies were negative. Carcinogenicity studies have not been performed with SURVANTA.

ADVERSE REACTIONS

The most commonly reported adverse experiences were associated with the dosing procedure. In the multiple-dose controlled clinical trials, transient bradycardia occurred with 11.9% of doses. Oxygen desaturation occurred with 9.8% of doses.

Other reactions during the dosing procedure occurred with fewer than 1% of doses and included endotracheal tube reflux, pallor, vasoconstriction, hypotension, endotracheal tube blockage, hypertension, hypocarbia, hypercarbia, and apnea. No deaths occurred during the dosing procedure, and all reactions resolved with symptomatic treatment.

The occurrence of concurrent illnesses common in premature infants was evaluated in the controlled trials. The rates in all controlled studies are in Table 3.

TABLE 3

	All Controlled Studies		
Concurrent Event	SURVANTA (%)	Control (%)	P-Value[a]
Patent ductus arteriosus	46.9	47.1	0.814
Intracranial hemorrhage	48.1	45.2	0.241
Severe intracranial hemorrhage	24.1	23.3	0.693
Pulmonary air leaks	10.9	24.7	<0.001
Pulmonary interstitial emphysema	20.2	38.4	<0.001
Necrotizing enterocolitis	6.1	5.3	0.427
Apnea	65.4	59.6	0.283
Severe apnea	46.1	42.5	0.114
Post-treatment sepsis	20.7	16.1	0.019
Post-treatment infection	10.2	9.1	0.345
Pulmonary hemorrhage	7.2	5.3	0.166

[a]P-value comparing groups in controlled studies

When all controlled studies were pooled, there was no difference in intracranial hemorrhage. However, in one of the single-dose rescue studies and one of the multiple-dose prevention studies, the rate of intracranial hemorrhage was significantly higher in SURVANTA patients than control patients (63.3% *v* 30.8%, $P=0.001$, and 48.8% *v* 34.2%, $P=0.047$, respectively). The rate in a Treatment IND involving approximately 4400 infants was lower than in the controlled trials.

In the controlled clinical trials, there was no effect of SURVANTA on results of common laboratory tests: white blood cell count and serum sodium, potassium, bilirubin, creatinine.

More than 3700 pretreatment and post-treatment serum samples were tested by Western Blot immunoassay for antibodies to surfactant-associated proteins SP-B and SP-C. No IgG or IgM antibodies were detected.

Several other complications are known to occur in premature infants. The following conditions were reported in the controlled clinical studies. The rates of the complications were not different in treated and control infants, and none of the complications were attributed to SURVANTA.

Respiratory: lung consolidation, blood from the endotracheal tube, deterioration after weaning, respiratory decompensation, subglottic stenosis, paralyzed diaphragm, respiratory failure.

Cardiovascular: hypotension, hypertension, tachycardia, ventricular tachycardia, aortic thrombosis, cardiac failure, cardiorespiratory arrest, increased apical pulse, persistent fetal circulation, air embolism, total anomalous pulmonary venous return.

Gastrointestinal: abdominal distention, hemorrhage, intestinal perforations, volvulus, bowel infarct, feeding intolerance, hepatic failure, stress ulcer.

Renal: renal failure, hematuria.

Hematologic: coagulopathy, thrombocytopenia, disseminated intravascular coagulation.

Central Nervous System: seizures.

Endocrine/Metabolic: adrenal hemorrhage, inappropriate ADH secretion, hyperphosphatemia.

Musculoskeletal: inguinal hernia.

Systemic: fever, deterioration.

Follow-Up Evaluations

To date, no long-term complications or sequelae of SURVANTA therapy have been found.

Single-Dose Studies

Six-month adjusted-age follow-up evaluations of 232 infants (115 treated) demonstrated no clinically important differences between treatment groups in pulmonary and neurologic sequelae, incidence or severity of retinopathy of prematurity, rehospitalizations, growth, or allergic manifestations.

Multiple-Dose Studies

Six-month adjusted age follow-up evaluations have not been completed. Preliminarily, in 605 (333 treated) of 916 surviving infants, there are trends for decreased cerebral palsy and need for supplemental oxygen in SURVANTA infants. Wheezing at the time of examination tended to be more frequent among SURVANTA infants, although there was no difference in bronchodilator therapy.

Twelve-month follow-up data from the multiple-dose studies have been completed in 328 (171 treated) of 909 surviving infants. To date no significant differences between treatments have been found, although there is a trend toward less wheezing in SURVANTA infants in contrast to the six month results.

OVERDOSAGE

Overdosage with SURVANTA has not been reported. Based on animal data, overdosage might result in acute airway obstruction. Treatment should be symptomatic and supportive.

Rales and moist breath sounds can transiently occur after SURVANTA is given, and do not indicate overdosage. Endotracheal suctioning or other remedial action is not required unless clear-cut signs of airway obstruction are present.

HOW SUPPLIED

SURVANTA (beractant) Intratracheal Suspension is supplied in single-use glass vials containing 8 mL of SURVANTA (NDC 0074-1040-08). Each milliliter contains 25 mg of phospholipids (200 mg phospholipids/8 mL) suspended in 0.9% sodium chloride solution. The color is off-white to light brown.

Store unopened vials at refrigeration temperature (2-8°C). Protect from light. Store vials in carton until ready for use. Vials are for single use only. Upon opening, discard unused drug.

June, 1991

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Primary duties in surgical areas, Lung Transplant, and Open Heart Recovery. Candidates must possess superior ICU skills in patient evaluation, knowledge of pressure-control ventilation, hemodynamic and hemodynamic monitoring. Requirements include obtaining an RRT within 3 years, ICU experience, ACLS Certification. Knowledge of independent lung ventilation preferred.

PEDIATRICS/NEONATAL

Provide Respiratory Care for Pediatrics/Neonatal patient populations while servicing an acute level III neonatal ICU with step-down area, acute-care pediatric ICU with IMC, general-care patient beds and the Pediatric Emergency Room. Requirement include 2 years of previous experience in a critical care setting and strong desire to learn about Pediatric/Neonatal patient populations. Preference will be given to those with specialty certification in Pediatric/Neonatal Respiratory Care.

All Position require Maryland State License or eligibility.

UMMS offers a competitive salary and a comprehensive benefits package. Interested candidates should submit resumes to:

The University of Maryland Medical System

Lorie A. Pater, Recruiter
Department of Human Resources
22 South Greene Street, Box 196
Baltimore, MD 21201
An Equal Opportunity Employer

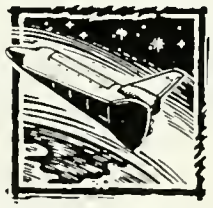
UNIVERSITY OF MARYLAND MEDICAL SYSTEM

FLORIDA

FLORIDA

For An Inviting Temporary Assignment...

There's No Place Like Holmes!



Our innovative, technologically advanced hospital system, located in East Central Florida, offers experienced Respiratory Therapists challenging 13-WEEK TEMPORARY ASSIGNMENTS! We're proud to provide the following features to those who join our Winter Team:

• Premium salary • Housing subsidy • No state income tax • Relaxed oceanfront community • Close proximity to Kennedy Space Center • Bonus for full-time work with less than 3 absences • Easy access to Orlando and its famous attractions

So if you've been looking for a change of pace for your career, there's no place like Holmes! Act now to be considered for one of these full-time temporary Winter Team assignments! Contact Monia Yust, Director of Employment, at 407-676-7110. Or send your resume to Monia at: Holmes Regional Medical Center, 1350 S. Hickory St., Melbourne, FL 32901. We are an equal opportunity employer.

HOLMES REGIONAL MEDICAL CENTER, INC.

468-bed Holmes Regional Medical Center • 60-bed Palm Bay Community Hospital

RESPIRATORY THERAPISTS

Put your career on the move with Hospital Therapy Service. Rapidly expanding company needs full or part time respiratory therapists for all shifts in Florida. Our ideal candidate will be a motivated Therapist experienced in the Healthcare industry, particularly in a Long Term Care facility. Areas available immediately are: Tallahassee, Ocala, West Palm Beach, Pompano, Ft. Myers, Bradenton, Venice, Clearwater, Dade City, St. Petersburg, Plant City, Lakeland, Winter Haven and Orlando. Coverage required every other weekend. Prefer RRT.

Please call

Carol Tomlinson

HOSPITAL THERAPY SERVICE

813-379-0005

REGISTERED RESPIRATORY THERAPISTS

Some Call It Paradise,
Other Call It Home

...but Vero Beach can be both to you when you join IRMH, a 347-bed, acute care facility in beautiful Vero Beach, Florida.

We offer competitive salary/benefits and the amenities of our sunny, south Florida location. For more information, contact Steve Massey, Recruiter, at 1-800-226-IRMH, ext. 1127,

IRMH Indian River Memorial Hospital

1000 36th Street
Vero Beach, FL 32960

EOE

RESPIRATORY THERAPIST

Florida license required. Respiratory therapist needed for full-time night shift with critical care experience preferred. Please send resume/salary requirements/history to:

Human Resources Dept.
West Orange Hospital
555 N. Dillard St.
Winter Garden, FL 34787

EOE

INDIANA

Memorial...
the preferred provider of

OPPORTUNITY

People talk. And the word is that the premier health care provider in the region also provides the number one career setting for over 2,000 employees. Why Memorial Health System? Our people tell us it's the opportunity to have a say in things, to continue learning at the forefront of medicine, to be recognized for quality, and to achieve lofty goals. There's much more to the picture. Be part of it all as:

• RESPIRATORY THERAPIST

As one of the largest, most progressive hospitals in Northwest Indiana, we maintain a dynamic environment, a strong sense of community, relocation assistance, and a highly competitive compensation/benefits package.

For more information about available positions call Carol Lyle-Ford, Allied Health Recruiter, **(219) 284-7407** or send resume to: Memorial Hospital of South Bend, 615 N. Michigan, South Bend, IN 46601. Equal opportunity employer.

Memorial
Health System

INDIANA

Respiratory Therapists

$1,000. Sign On Bonus

Respiratory Therapists
$1,000 Sign On Bonus

We are a highly motivated healthcare organization, seeking equally motivated & credentialed Respiratory Care Practitioners. Our rapidly expanding organization has what talented therapists are looking for:

- **Proven Track Record for Career Advancement Opportunities**
- **401K Retirement Plan**
- **Comprehensive Insurance Package**
- **Competitive Wage and Salary Program**

Management opportunities, as well as Full-time, Part-time and shift positions are available throughout Indiana, including:

• Carmel • Hanover • Indianapolis • Michigan City • Munster • New Castle • Richmond • Shelbyville • Wabash Winchester

Join our team today! Contact Sharon Lewis at: 1-800-999-3277, Monday through Friday

Advanced Care Medicine, Inc.
A subsidiary of Continental Medical Services, Inc.
An Equal Opportunity Employer

Acmed

MICHIGAN

Respiratory Therapists

Mount Clemens General Hospital is a 288-bed acute care teaching facility. The Respiratory Care Department has part-time and contingent positions on all shifts.

We offer excellent benefits and salary commensurate with experience. For consideration, complete an application or submit a resume to Mount Clemens General Hospital, Human Resources, 1000 Harrington Blvd., Mt. Clemens, MI 48043, 313–466–8085.

Mount Clemens
General Hospital

A Subsidiary of MCG Telesis
Equal Opportunity Employer

INDIANA

$1,000 Sign-On Bonus

CERTIFIED RESPIRATORY TECHNICIAN

Our hospital has full time positions for Respiratory Technicians on 2nd and 3rd shifts, including every other weekend. Salary based on experience, excellent benefit package plus $1,000 sign-on bonus.

Apply or send resume with cover letter to:
Human Resources Dept.

Jackson County Schneck
Memorial Hospital
200 S. Walnut St.
Seymour, IN 47274
EOE

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Call (214) 243-2272
For a Membership Application

WISCONSIN

RESPIRATORY CARE PRACTITIONER

Kenosha Hospital and Medical Center is seeking a full time, state certified or eligible Respiratory Care Practitioner for the PM shift. Become a member of our full service Respiratory Care Department. Comprehensive benefit package and salary commensurate with experience. To apply, please send resume or apply in person:

KENOSHA HOSPITAL
& MEDICAL CENTER

Personnel Department
6308 - Eighth Avenue
Kenosha, Wisconsin 53143
EOE

Respiratory Therapists
SIGN ON BONUS

Certified and Wisconsin licensed respiratory therapist interested in full or part time, 2nd shift hours, competitive salary, flexible 8 and 12 hour shifts, innovative benefits, and the rewards of pediatrics should call 1-800-766-6336 or forward resume to:

Children's Hospital
of Wisconsin
P.O. Box 1997 - M.S. 951
Milwaukee, Wisconsin 53201
Affirmative Action Employer

OHIO

AKRON, OH

RESPIRATORY CARE OPPORTUNITIES

Summa Health System, a 970-bed system dedicated to excellence in patient care, medical education and research, has the following positions available at Summa Health System.

• Supervisor, Respiratory Therapy 11pm to 7:30am shift, St. Thomas campus. Applicants must have a minimum two years respiratory experience and be a registered therapist.

• Part time evenings and night Registered Respiratory Therapists or certified Respiratory Technicians on both the Akron City and St. Thomas campuses.

Applicants must be eligible for Ohio license. Excellent benefits and competitive salary. Please submit resume or apply in person to: **Dept. of Human Resources, Akron City Hospital, 525 East Market St., Akron, Ohio 44309.** Equal Opportunity Employer.

SUMMA
Health System

Member Hospitals
Akron City Hospital
St. Thomas Medical Center

RESPIRATORY CARE

Growth and Development of the Pulmonary Services Department is offering new full and part time job opportunities for professionally motivated registered and registry-eligible licensed therapists.

The Pulmonary Services Department offers a progressive and assertive approach to Respiratory Care. Our career-minded Respiratory Therapists are integral members of the health care team with responsibilities that include patient assessments for determination of appropriateness of respiratory care, all aspects of airway management, assertive mechanical ventilation management and weaning, exposure to diagnostics inclusive of metabolic monitoring, new programs in hyperbaric medicine and sleep disorder testing plus opportunities to participate in the lifestar program (Mobile Intensive Care Unit).

We are located 5 minutes from I-77 and I-71. We offer a competitive wage and flexible benefit package, including tuition reimbursement for part and full time employees, paid A.A.R.C. membership dues, paid licensure fees, free parking and uniforms. Attendance of our annual SVCH & HC Respiratory Care Seminar provides free CRCE credit for staff. Interested candidates should call (216) 363-2544 and/or submit a resume to:.

Mrs. Pat Simmerman
Human Resources Department
Saint Vincent Charity Hospital & Health Center
2351 East 22nd Street
Cleveland, OH 44115
Equal Opportunity Employer M/F/H

OHIO

PARK MEDICAL CENTER

GREAT OPPORTUNITIES AWAIT YOU AT THE PARK.

Backed by extensive resources and advanced capabilities, Park Medical Center is fast becoming recognized as one of the region's most progressive healthcare facilities. Today, we seek enthusiastic, goal-oriented professionals who are graduates from an AMA-approved school of respiratory therapy, with RRT or eligibility or CRTT status.

In addition to boasting the latest technology, The Park also offers a competitive salary and top benefits. For immediate consideration, please forward your resume to: **Personnel Department, Park Medical Center, 1492 E. Broad St., Columbus, OH 43205.** EOE m/f/d.

ARKANSAS

ARKANSAS

UAMS MEDICAL CENTER

Diagnostic Services Manager

UAMS Medical Center is seeking to fill the position of Diagnostic Services Manager. Successful applicant will hold a Bachelor degree in Life Sciences, and be a Registered Respiratory Therapist with 2 years Arterial Blood Gases Laboratory experience (including CLIA & CAP) and possess good interpersonal skills.

Call (501) 686-5665, or send resume to:
UAMS Human Resources
4301 West Markham
Little Rock, Arkansas 72205

UAMS Medical Center and The University of Arkansas for Medical Sciences are Equal Opportunity Employers

ARKANSAS

ARKANSAS

UAMS MEDICAL CENTER

Director of Medical Services

UAMS Medical Center is seeking a Director of Medical Services. Successful applicant will hold a Bachelor of Sciences (BS) degree, and preferrably a Masters degree in Business or Health-related field, and be a Registered Respiratory Therapist with 3-5 years of management experience with appropriate interpersonal skills.

Areas of responsibility will include Respiratory Care Services, Arterial Blood Gases, Pulmonary Function Testing, Endoscopy Laboratory, and Heart Station.

Call (501) 686-5665, or send resume to:
UAMS Human Resources
4301 West Markham
Little Rock, Arkansas 72205

UAMS Medical Center and
The University of Arkansas
for Medical Sciences are
Equal Opportunity Employers

TEXAS

TEXAS

Where Talent and Caring Go Hand-in-Hand...

Cook-Fort Worth Children's Medical Center is a 184-bed, secondary referral hospital in Fort Worth, Texas. Located in the Dallas/Fort Worth metroplex, we serve a 50-county referral area in North Central and West Texas. The facility houses 12 outpatient clinics, and the emergency department is the only designated pediatric trauma receiving center in the region.

Our Respiratory Care Specialists staff a 34-bed Neonatal Intensive Care Unit, a 15-bed Pediatric Intensive Care Unit and also have the opportunity to become a member of our ground, fixed wing, and helicopter Transport Team.

Our extraordinary healthcare environment calls for exceptional talents. If you are interested in exploring the opportunities available for RRTs, please contact **Nancy M. Jones, Employment Specialist at (817) 885-4415. Or write: Cook-Fort Worth Children's Medical Center, 801 Seventh Avenue, Fort Worth, TX 76104. EOE.**

CMC
COOK-FORT WORTH
CHILDREN'S MEDICAL CENTER

ASSISTANT DIRECTOR RESPIRATORY THERAPY

St. Joseph Hospital and Health Center, Bryan-College Station, a 204-bed acute-care facility, has an immediate opening for an RRT with at least 3-5 years experience to include supervisory experience to serve as Assistant Director. This position will manage daily operations and QA.

Conveniently located between the Houston, Dallas, San Antonio and Austin metro areas, Bryan-College Station offers small town living with a big city atmosphere. The selected individual can look forward to an outstanding compensation and benefits package.

For more information, call Kendall Turton at **(409) 776-2515** or send a resume with cover letter to:

St. Joseph Hospital and Health Center
Human Resources Department
2801 Franciscan Drive
Bryan, Texas 77802
E.O.E.

UTMB GALVESTON

CLINICAL SPECIALISTS

The University of Texas Medical Branch at Galveston has the following opportunities available:

12-HOUR DAY/ NIGHT POSITIONS

Requirements include RRT and 5 years ICU experience. A Bachelor's degree, CPFT, and supervisory experience preferred.

BENEFITS

• Premium Sharing • Teacher Retirement System • Redirection Accounts (ask us about these) • Tuition Reimbursement • Three weeks vacation + holidays • NO STATE INCOME TAX

For further information, call **(409) 772-8189 Collect,** or write to: **Pulmonary Care Services, THE UNIVERSITY OF TEXAS MEDICAL BRANCH, E-90, Galveston, Texas 77555-0890.** UTMB is an equal opportunity/affirmative action employer m/f/d/v. UTMB is a smoke-free, drug-free workplace. UTMB employs only individuals eligible to work in the U.S.

Critical Care Respiratory Therapists

Due to recent department restructuring, we now have opportunities for Registered Respiratory Therapists with Critical Care experience, (pediatric experience preferred).

Growth opportunities include specialization in ECMO and HFOV. Full time, 8-hour shifts, Monday through Friday (no weekends). For more information and appointment, please call the Allied Health Recruiter at 214/640-2163 or 1-800-852-0982.

children's
MEDICAL CENTER OF DALLAS
1935 Motor Street • Dallas, Texas 75235 • (214) 920-2000

Equal Opportunity Employer M/F/D

TEXAS

TEXAS

"After working in Respiratory Care at other hospitals, St. Luke's is like a breath of fresh air."
Mayo Mullone, BS, RRT, RCP
Respiratory Care

St. Luke's offers Respiratory Therapists like Mayo the opportunity to work more closely with doctors. As Mayo says, "Everybody on the team, including the doctors, operates on the same level with the same goal of helping the patient get better. I've been here five years; there's no better place to build a career than St. Luke's."

ST. LUKE'S
Episcopal Hospital

Step up to the benefits of working at St. Luke's in Houston's Texas Medical Center. Call collect (713)791-3995 or send your resume to our Employment Office (4-293), P.O. Box 20269, Houston, Texas 77225-0269.

Visit us at Booth #165 during the AARC National Conference.

An Equal Opportunity Employer, M/F/H/V Non-smokers preferred

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AARC ADVANTAGE

Call
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For a
Membership
Application

¡JOIN THE FIESTA!

at the AARC
Annual Meeting
December 12-15
in San Antonio, TX

TEXAS

Respiratory Care Registered/Registry Eligible Night Shift (M-F)

The Respiratory Care Department is accepting applications for staff positions in its Acute Care areas. Responsibilities will include involvement in the Bone Marrow Unit, Cardiac Care, Liver Transplantation, ventilator management, and PRN rotation in the Critical Care and Emergency Referral Center areas. Lead therapists opportunities available:

- Up to $16.96 an hour (depending on experience and credentials)
- Wide variety of in-house CEU's offered
- No weekends
- Overtime options available
- Additional salary credits for pediatric experience.

For more information and appointment, please contact the Allied Health Recruiter at 214/640-2163 or 1-800-852-0982.

children's
MEDICAL CENTER OF DALLAS
1935 Motor Street • Dallas, Texas 75235 • (214) 920-2000

Equal Opportunity Employer M/F/D

Respiratory Care Supervisors

Are you looking for an opportunity to exercise your managerial expertise in a teaching pediatric facility? Some attributes that set these positions apart from others are:

- No expectation to carry a patient load
- On-going in-house management development
- Involved with short and long term planning
- Management development of ICU team leaders and lead therapists in Acute Care
- Management of staffing and operations of the Emergency Referral Center, ICU, and Acute Care areas
- Non-salaried, with overtime available
- Up to $18.55 an hour (depending on experience)

Registered Therapist with management experience can contact the Allied Health Recruiter at 214/640-2163 or 1-800-852-0982 for further information and appointment.

children's
MEDICAL CENTER OF DALLAS
1935 Motor Street • Dallas, Texas 75235 • (214) 920-2000

Equal Opportunity Employer M/F/D

No more mix-up or lost stethoscope with a Stethoscope ID Tag. One side provides space for identification and the other bears the *"Respiratory Care...Cares"* slogan. 5/8" x 1 1/2" tag fastens around stethoscope with an adhesive strip.
Item R47—$4 each (AARC member $1.90). Add $1 for shipping and handling for one; 30¢ each additional.

To Order Call (214) 243-2272 or Fax to (214) 484-6010

GET THE RECOGNITION YOU DESERVE

Work with your hospital public relations department to get the recognition you deserve. Keep them informed of your department's activities and personnel changes. If your PR department doesn't know about your recent promotion or your department's expansion of services, they certainly can't write an article about it for the hospital publication or local news.

PUBLIC RELATIONS BEGIN WITH YOU

AMERICAN ASSOCIATION FOR RESPIRATORY CARE
11030 Ables Lane
Dallas, TX 75229-4593
(214) 243-2272

ILLINOIS

New Beds. New Opportunities.

Join us as we expand our Peds ICU!

At The Children's Memorial Medical Center, you'll find an environment that's always growing. Packed with energy and enthusiasm, this is no ordinary place to practice.

What makes it so different here? It's the kids! Plus a whole lot more!

- Unit-based positions
- State-of-the-art technology
- Patient and family-centered environment
- 6-week individualized orientation
- Ongoing education inservices
- Bonus programs for nites and extra weekends
- Higher registry rates
- Pre-paid tuition reimbursement

You'll love the hopeful, friendly atmosphere of our world-renowned pediatric healthcare facility. Join us!

For confidential consideration, please contact: Jim Mulvihill, Employment Specialist, (312)880-6344, The Children's Memorial Medical Center, 2300 Children's Plaza, Chicago, IL 60614. EOE.

Children's CHICAGO
THE CHILDREN'S MEMORIAL MEDICAL CENTER

NBRC ENTRY LEVEL EXAMINATION STUDY AIDS

NBRC Entry Level Examination tutorials are specially written to help you pass two of the most difficult sections of the examination. Uses questions now retired from the actual examination question pool (used with permission of Applied Measurement Professionals, Inc., a wholly owned subsidiary of the NBRC).

Tutorial I: Detecting Equipment Malfunctions. Item CD4 — $39.95 ea. (AARC member $29.95). Add $4.50 for shipping and handling.

Tutorial II: Evaluate & Monitor Patient's Response to.Respiratory Care, Assess Patient Response. Item CD5 — $39.95 ea. (AARC member $29.95). Add $4.50 for shipping and handling.

Order both tutorials and save! Item CD6 — $75 Set (Member $55). Add $5.50 for shipping and handling.

To Order Call (214) 243-2272 or Fax to (214) 484-6010

Learn What *Not To Do* With A COPD Patient

The Hospitalized COPD Patient: 10 Commandments for the Clinician — By David J. Pierson, MD. Takes you inside the decision-making process of caring for a respiratory care patient with chronic obstructive pulmonary disease. Details the "10 commandments" for the clinician to follow when encountering the 10 most serious problems the COPD patient can present to the hospital. Emphasis will focus on the *"what-not-to-do."*

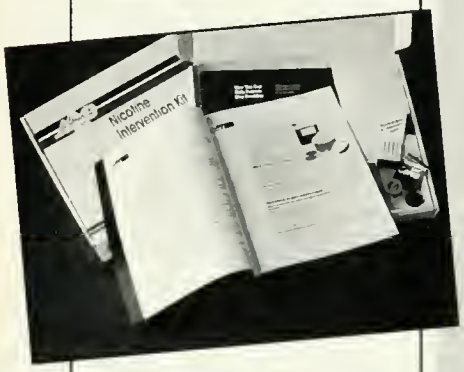
Item VT29 — VHS (60 minutes) $40 (Member $35) Add $3 for shipping.

Call
(214) 243-2272
or FAX Your Order to
(214) 484-2720

American Association for Respiratory Care
11030 Ables Lane
Dallas, TX
75229-4593

RESPIRATORY CARE CARES

Share RC Information & Help Your Community Breathe Easier



The Nicotine Intervention Kit (NIK)

A complete do-it-yourself package for establishing a nicotine dependency intervention program in your institution. NIK contains a videotape to introduce the program to your administrators and staff, a business plan, a program outline, reproducible forms for patient education, and a resource list for use in education and training of patients and staff. A great way to help your patients and expand your department's services.

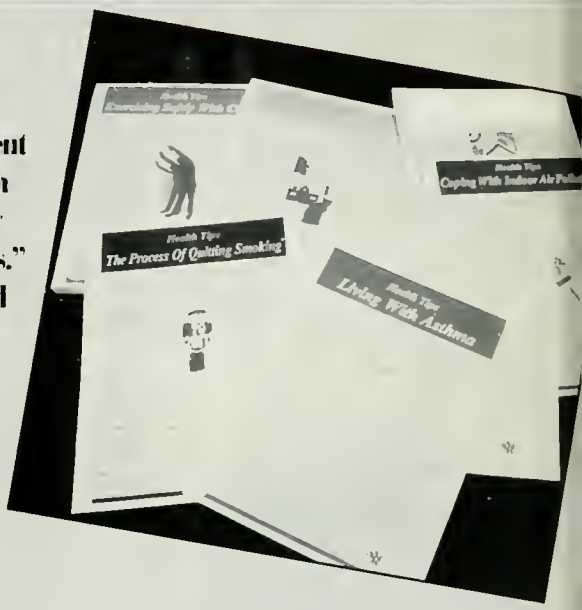
Item R50

$70 Ea
(Member $50)

To Order Call
(214) 243-2272
FAX (214) 484-2720

Use these health tips sheets as a community relations tool or for patient education. Sharing this information with your patients and community shows that "Respiratory Care…Cares." Comes 50 to a pad. Convenient and easy to tear off.

$10 Ea, Pad 50
(Member $5)



Helping Your Child Breathe Easier — More tips from the AARC for helping alleviate respiratory problems in children. Presents pointers on colds, flu, allergies, and other childhood respiratory illnesses. **Item R23**

Secondhand Smoke — This brochure offers topical information about the effects of exposure to secondhand smoke and how to avoid it in public, at the office, and in the home. **Item R24**

Eating Right: Tips for the COPD Patient — Patients with lung disease must be more careful than most about following good nutrition. Includes tips on what to eat and avoid and the best times for eating. **Item R25**

Dealing with Allergies — More than 35 million Americans suffer from allergies, and this sheet gives them pointers on reducing or avoiding exposure to allergens, preventing respiratory infection, and using medications as instructed. **Item R30**

Minimizing the Effects of Outdoor Air Pollution — Everyone is adversely affected by air pollution. This tip sheet discusses avoidance of exposure to noxious fumes and the importance of staying updated on pollution reports. **Item R31**

Living with Asthma — Ten million U.S. citizens have asthma, and this tip sheet gives them pointers on following their doctor's advice. Also helps them understand medications, avoid triggers, and maintain good health. **Item R32**

The Process of Quitting Smoking — Every year, three million smokers give up cigarettes. You can help others quit with these tips on how they can start the process. **Item R33**

Coping with Indoor Air Pollution — Indoor air pollution affects everyone. This tip sheet gives pointers on coping with 13 types of indoor air pollution from tobacco smoke to radon gas. **Item R34**

Exercising Safely with COPD — COPD patients need exercise, too, and this tip sheet gives advice on doing it safely from warm-up to cool-down. **Item R35**

Lessening the Effects of COPD — Much can be done to lessen the side effects and symptoms of COPD. This sheet gives advice on how these patients can lead an active and rewarding life. **Item R36**

Please Add Shipping
$15 or less – $3.25
$16 to $30 – $3.25
$31 to $50 – $4.50

Requirements For Traveling With Oxygen

Oxygen patients who travel need to know the requirements for the various carriers they use. This handy eight-page booklet contains phone numbers and basic requirements for airlines, cruise lines, the Greyhound bus system, and AMTRAK.

BK16

$20, Pkg 50
(Member $10)

See page 1386 for order form

EXHIBITORS

at the 38th Annual Meeting and Exposition
of the
American Association for Respiratory Care

December 12-15, 1992
San Antonio, Texas

Thousands of examples of respiratory care equipment and supplies are displayed, discussed, and demonstrated in the exhibit booths at the Annual Convention. The AARC thanks the firms that support the Association by exhibiting. (Exhibitors confirmed by October 20, 1992, are listed.)

Exhibit Hours

Saturday, December 12	12 noon - 4:00 pm
Sunday, December 13	11:00 am - 4:00 pm
Monday, December 14	11:00 am - 4:00 pm
Tuesday, December 15	11:00 am - 3:00 pm

Exhibitor	Booth
A	
Abbey Home Healthcare	399A
Advance for Respiratory Care Practitioners	199
Aequitron Medical, Inc.	151
Airborne Life Support Systems	577
Air Response Air Ambulance	1007B
Airco Medical	598
Allen & Hanburys	323
Allied Healthcare Products, Inc.	145
American Mobile Therapists	154
Anesthesia Associates, Inc.	318
ARC Medical, Inc.	126
Arkansas Children's Hospital	705
ARTEC, Inc.	912
Arvee Medical, Inc.	162 & 164
Automatic Liquid Packaging, Inc.	451 & 453
AVL Scientific Corporation	268, 270, 272, 274, 276
B	
B & B Medical Technologies, Inc.	901
Ballard Medical Products	215, 217, 514
Baxter Pharmaseal Division	223
Bay Corporation	906 & 908
Baylor University Medical Center	709
BCI International	414 & 416
Bear Medical Systems, Inc.	345
Becton Dickinson Division	398A
Bicore Monitoring Systems	581
Bio-Med Devices, Inc.	315 & 317
Bio-Rad Laboratories	647
Biomedical Sensors/Pfizer Hospital Products Group	908A & 910
Biosafety Systems, Inc.	161
Bird Products Corporation	261
Bivona, Inc.	621 & 623
Bunnell Incorporated	491
Burroughs Wellcome Company	649 & 651
C	
California College for Health Sciences	903 & 905
Carie Med-Tech, Inc.	694
Center Laboratories	674A
Chad Therapeutic, Inc.	699
Children's Medical Center-Dallas	635
Churchill Livingstone, Inc.	1015
Ciba Corning Diagnostics Corporation	135
Clement Clarke	136

Exhibitor	Booth
CNS, Inc.	611, 613, 615
Cobe Cardiovascular, Inc.	710
Concord/Portex	332 & 334
Consentius Technologies	188
Corometrics Medical Systems	115
Criticare Systems, Inc.	700
Curant Communications/RT Magazine	637 & 639
Cybermedics, Inc.	119
D	
Dale Medical Products, Inc.	811
DataStar Education Systems & Services, Inc.	297
Datex Medical Instrumentation, Inc.	140
Del Mar Avionics	186
Delmar Publishers, Inc.	195
DeVilbiss Health Care, Inc.	550 & 552
Dey Laboratories, Inc.	415 & 417
Diamond Software	536
Diemolding Healthcare Division-DHD Medical	314 & 316
Dräger, Inc.	487
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Edentec	1000 & 1002
Encyclopaedia Britannica	187
Environmental Tectonics Corporation	498
ErgoMed, Inc.	497
Ethex International, Inc.	1014
Evergreen Pharmaceutical Service	1007A
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F.A. Davis Company/Publishers	490
Ferraris Medical, Inc.	418
Fisher & Paykel Healthcare	233 & 235
Fisons Pharmaceuticals	449
FloCare Medical	804
Florida Hospital	197
Futuremed	499
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General Biomedical Service, Inc.	106 & 108
General Physiotherapy, Inc.	516
Gibeck-Dryden	691
The Gideons International	603
Goldstein & Associates, Inc.	395
Graham-Field, Inc.	1010
Greenery Rehabilitation Group, Inc.	492
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Hamilton Medical, Inc.	279
Hans Rudolph, Inc.	177
Health Educator Publications, Inc.	617
Healthdyne Technologies	385
Healthmark Industries	245
HealthScan Products, Inc.	114 & 116
Heart to Heart	298A
Hermann Hospital-Houston	703A
Homedco, Inc.	251 & 253
Hospitak, Inc.	619
HR, Incorporated	515
Hudson Respiratory Care, Inc.	423
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ICN Pharmaceutical, Inc.	915
Impact Medical Corporation	219
Infrasonics, Inc.	125
Innovative Medical Marketing	912A
Inspired Medical Products, Inc.	697
Instrumentation Industries, Inc.	662 & 664
Instrumentation Laboratory	101
Integrated Health Services	695
InterMedway	128
Intersurgical Incorporated	160
Intertech Resources	672 & 674
Invacare	659, 661, 663, 665
Invivo Research, Inc.	291 & 293
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J.B. Lippincott Company	159
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Joint Commission on Accreditation of Healthcare Organizations	104
Joint Review Committee for Respiratory Therapy Education	192
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KCI	551
King Systems Corporation	142 & 144
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Laboratory Data Systems	597
Laerdal Medical Corporation	344 & 346
LeMans Industries Corporation	814
Life Support Products, Inc.	601
LIFECARE	333
Linear Tonometers, Inc.	914
Liquid Carbonic	544 & 546

Exhibitor	Booth
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Notices of competitions, scholarships, fellowships, examination dates, new educational programs, and the like will be listed here free of charge. Items for the Notices section must reach the Journal 60 days before the desired month of publication (January 1 for the March issue, February 1 for the April issue, etc). Include all pertinent information and mail notices to RESPIRATORY CARE Notices Dept, 11030 Ables Lane, Dallas TX 75229-4593.

Notices

The American Respiratory Care Foundation Awards for 1992

Funded by Allen & Hanburys

1. $2,000 for the best original paper (study, evaluation, or case report) *accepted* for publication from December 1991 through October 1992. This award is *not* limited to papers based on OPEN FORUM presentations.
2. Four awards of $1,000 each for papers *accepted* for publication from November 1991 through October 1992 based on *any* OPEN FORUM presentation (not limited to 1991 OPEN FORUM).
3. Five awards of $500 each for the best papers *submitted* (not necessarily published) by 1992 OPEN FORUM participants who have 'never published' in the Journal. The never-published first author must present the abstract at the Annual Meeting and must submit a paper based on the abstract before the 1992 Annual Meeting (*received* in the Editorial Office by November 1, 1992). Co-authors may have previously published in RESPIRATORY CARE.

Funded by Radiometer America

Three awards of $333 each are to be awarded to the authors of the three best features from Test Your Radiologic Skill, Blood Gas Corner, and PFT Corner accepted for publication from November 1991 through October 1992. All three (or none) of the features may be chosen from a specific category (eg, all three may be chosen from Blood Gas Corner).

Registration Reimbursement

As in the past, any 1992 OPEN FORUM presenter (or co-author designee) will receive complimentary registration for an adequately prepared paper based on his 1992 OPEN FORUM abstract, submitted prior to or at the 1992 Annual Meeting.

All awards will be made at the 1992 Annual Meeting. Papers are judged automatically. No application is necessary.

THE NATIONAL BOARD FOR RESPIRATORY CARE—1992 Examination and Fee Schedule

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Application Deadline:	September 1, 1992

RRT Examination

EXAMINATION DATE:	DECEMBER 5, 1992
Applications Accepted Beginning:	June 1, 1992
Application Deadline:	August 1, 1992

RPFT Examination

EXAMINATION DATE:	DECEMBER 5, 1992
Applications Accepted Beginning:	July 1, 1992
Application Deadline:	September 1, 1992

Perinatal/Pediatric Specialty Examination

EXAMINATION DATE:	MARCH 13, 1993
Applications Accepted Beginning:	September 1, 1992
Application Deadline:	November 1, 1992

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Entry Level CRTT—reapplicant:	$ 60.00
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Written Registry Only—new applicant:	$ 90.00
Written Registry Only—reapplicant:	$ 60.00
Clinical Simulation Only—new and reapplicant	$100.00
Entry Level CPFT—new applicant:	$100.00
Entry Level CPFT—reapplicant:	$ 80.00
Advanced RPFT—new applicant:	$150.00
Advanced RPFT—reapplicant:	$130.00
Perinatal/Pediatric—new applicant:	$150.00
Perinatal/Pediatric—reapplicant:	$130.00

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RRT Recredentialing:		
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Clinical Simulation Examination	$65.00	$100.00
CPFT Recredentialing:	$25.00	$ 80.00
RPFT Recredentialing:	$25.00	$130.00
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Calendar of Events

Not-for-profit organizations are offered a free advertisement of up to eight lines to appear, on a space-available basis, in Calendar of Events in RESPIRATORY CARE. Ads for other meetings are priced at $5.50 per line and require an insertion order. Deadline is the 20th of the month two months preceding the month in which you wish the ad to run. Submit copy and insertion orders to Calendar of Events, RESPIRATORY CARE, 11030 Ables Lane, Dallas TX 75229-4593.

AARC & AFFILIATES

November 17 Nationwide. The AARC, in conjunction with VHA Satellite Network, presents "Prevention of Postoperative Atelectasis and Pneumonia," one in a series of live satellite videoconferences titled "Professor's Rounds in Respiratory Care." Featured presenters are David J Pierson MD and Richard Branson RRT. Site registration for entire staff is $245 for AARC members. Call (214) 830-0061.

December 12-15 in San Antonio, Texas. The AARC presents its 38th Annual Convention and Exhibition at the San Antonio Convention Center. The event features four days of meetings and lectures covering all facets of respiratory care. The Exhibit Hall showcases more than 300 companies exhibiting in over 500 booths. It promises to be ¡Fantástico! For details, refer to the Convention information in this issue or contact the AARC Conventions Department, 11030 Ables Ln, Dallas TX 75229-4593. (214) 243-2272, fax (214) 484-2720.

February 16-19 in Reno, Nevada. The American Lung Association of Nevada and The Nevada Society for Respiratory Care present the 12th Annual High Sierra Critical Care Conference at the Peppermill Hotel Casino. Topics include adult, pediatric, and neonatal critical care issues. Contact Donna Turner, American Lung Association of Nevada, PO Box 7056, Reno NV 89510, (702) 829-5864 (9 AM-3 PM PST).

OTHER MEETINGS

November 6 in Reno, Nevada. The American Lung Association of Nevada presents the 11th Annual Respiratory Health Conference at Washoe Medical Center. Contact Donna Turner, American Lung Association of Nevada, PO Box 7056, Reno NV 89510-7056, (702) 829-5864 (9 am to 5 pm PST).

November 13 in Wilmington, Delaware. The 1st Annual Delaware Pediatric Pulmonary Symposium held at the Alfred I duPont Institute. The meeting is co-sponsored by AIDI's respiratory care, pediatrics, and nursing departments and American Lung Association of Delaware. Call (302) 651-6750.

November 18 in Huron, Ohio. The American Lung Association of Ohio's South Shore presents the 3rd Annual North Coast Pulmonary Disease Conference at the Sawmill Creek Resort. Topics include transplantation and aftercare, pulmonary embolism, fatal airway disease, and BiPAP and nasal ventilation. Guest speakers include Gregory R Owens MD, Thomas J Kirby MD, and Joseph A Golish MD. Contact the American Lung Association (419) 663-5864.

November 18-21 in Miami Beach, Florida. The University of Miami, Division of Neonatology-Department of Pediatrics, presents its Annual Neonatal Symposium, "New Developments in Neonatal Respiratory Care," at the Doral Ocean Beach Resort. The symposium includes lectures, discussions, and a workshop on pulmonary function testing in neonates. Contact Charles R Bauer MD, Program Co-Director, University of Miami-Department of Pediatrics (R-131), PO Box 016960, Miami FL 33101. (305) 547-5808, fax (305) 547-3501.

January 8-10, 1993 in Naples, Florida. The National Association of EMS Physicians holds its Winter Meeting at the Ritz Carlton. The meeting addresses challenges in EMS education and controversies in prehospital therapeutics. For further information, contact Kathleen Stage-Kern, NAEMSP Executive Director, at (412) 578-3222.

March 3-5, 1993 in Lyon, France. The Journées Internationales de Ventilation à Domicile presents the International Conference on Home Mechanical Ventilation. The meeting includes scientific sessions, practical education sessions, and poster presentations and exhibits. Simultaneous translation (French/English) is offered. Deadline for abstracts is December 1992. Write: JIVD (SRMAR) 93, Grande Rue de la Croix-Rousse, 69317 Lyon Cedex 04, France. Call (33) 78 39 08 43, fax (33) 78 29 98 94.

March 24-27, 1993 in Helena, Montana. The American Lung Association of Montana presents the Twelfth Annual Big Sky Pulmonary Ski Conference. Contact the American Lung Association of Montana, 825 Helena Ave, Helena MT 59601, (406) 442-6556, FAX: (406) 442-2346.

October 24-29, 1993, in Jerusalem, Israel. The XIVth World Congress of Asthmalogy convenes in Jerusalem. Topics presented include molecular biology in lung disease, cells involved in asthma, and house dust mite and asthma. Abstracts are currently being accepted. For more information, contact Gil-Kenes, 1617 JFK Blvd, Suite 946, Philadelphia PA 19103. (800) 223-3855.

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Hospital Acquired Pneumonia

By Galen B. Toews, MD. Provides information on the epidemiology, pathogenesis, and management of nosocomial pulmonary infections. **Item VT36**

Smoking Cessation: Intervention Techniques For the Respiratory Care Practitioner

By Kathleen A. Smalky, MD, MPH. Covers four major aspects of smoking cessation — the impact of smoking on illness and mortality, behavioral components, current cessation programs, and effective intervention. Discusses identification of the physically addicted smoker and the effects of nicotine withdrawal. **Item VT35**

Nutrition and Respiratory Care

By Rich Branson, RRT. Explains the relationships and interactions of malnutrition on ventilatory drive, respiratory muscles, lung structure, and immunity. Further discusses the effects of nutrients on the respiratory system, particularly the nutritional support needed by mechanically ventilated and COPD patients. **Item VT34**

Uses and Abuses of Non-Invasive Monitors in Respiratory Care

By Dean Hess, RRT. Presents a discussion of how much noninvasive monitoring is needed, proof of false positives, its financial impact, and its future. Discusses the various methods: transcutaneous, pulse oximetry, and capnography. **Item VT33**

Sleep Disorders

By Brian Foresman, MD. A discussion of the physiology of sleep and the kinds of respiratory and nonrespiratory sleep disorders seen in the hospital. Discusses how to spot sleep apnea, the problems caused by the inpatient hospital setting, sleep disorder diagnosis, and treatment. **Item VT32**

Sleep Apnea

By Alan K. Pierce, MD. Explains how sleep stages are related to respiratory patterns and blood gas values in both normal and abnormal subjects. Includes a discussion of the criteria for defining the sleep apnea syndrome and the distinguishing features of central, obstructive, and mixed causes of apnea. Also addressed is the efficacy of medical treatment to correct specific types of sleep apnea. **Item VT11**

Monitoring Respiratory Mechanics During Mechanical Ventilation

By Robert L. Chatburn, RRT. Explains how physical and mathematical models are developed and applied and how they are incorporated into ventilator design to provide estimates of mechanics and some of the problems that can develop because of the limitations of the models. **Item VT30**

Pressure Support Update

By Neil MacIntyre, MD. Reviews pressure support ventilation and how it is used. Explains waveforms for airway pressure, flow, and volume. Also illustrates the measurement of inspiratory muscle loads by pressure-time index and muscle V_{O_2}, and demonstrates how muscle efficiency changes as the character of work changes. Includes examples of low- and high-level PSV for elimination of the imposed work of breathing and as a weaning tool. **Item VT28**

Managing the Work of Breathing During Mechanical Ventilation

By John Marini, MD. Learn about the work of breathing and ways in which it can be minimized in the clinical setting on patients receiving mechanical ventilation. Focuses on diminishing the breathing workload through quantifying the effort during mechanical ventilation via direct measures such as oxygen consumption, electromyography, pressure-time index, and external work of breathing, as well as indirect measures. **Item VT27**

Modes of Conventional Ventilation

By Robert M. Kacmarek, PhD, RRT. A review of mechanical ventilation is presented, including the rationale for movement from one generation of ventilators to another. Ventilator modes discussed include control, assist/control, intermittent mandatory ventilation, synchronized intermittent mandatory ventilation, mandatory minute ventilation, and pressure support ventilation. **Item VT19**

Pressure Support Ventilation

By Neil MacIntyre, MD. This presentation defines and describes the physiological considerations attributed to PSV and the clinical situations when PSV may be useful. Includes comparisons when low-pressure levels and high-pressure levels of PSV are offered. Discussion includes using PSV to help overcome resistance for intubated patients and as an augmented ventilatory mode of weaning. **Item VT17**

Theory and Application of Neonatal Ventilation

By Robert Chatburn, RRT. Knob-turning in the neonatal intensive care unit should be a profound activity because it often has profound consequences. Adjustment of a single control on a ventilator generally has multiple effects, and thorough consideration of how controls are interrelated is essential for optimum care. Presents a well-organized and systemic approach for managing mechanical ventilation. **Item VT25**

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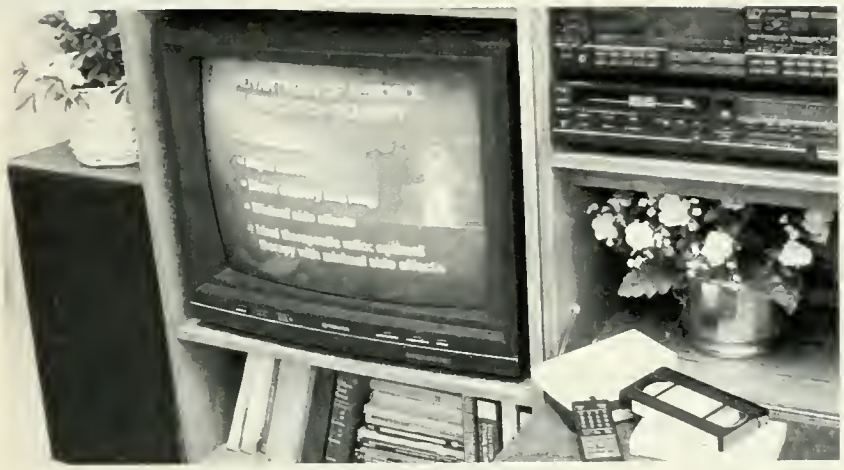

Fetal Lung Development

By Charles Rosenfeld, MD. Examines the four anatomical phases of fetal lung development along with a discussion of the biochemical development of the fetal lung through gestation. Includes a description of the substances in surfactant, the importance of their timely development, and the methods used to assess fetus survivability by using tracheal aspirant to identify the necessary ratios of the phospholipids making up surfactant. **Item VT23**

ARDS Review

By Tony Dal Nogare, MD. Discusses the latest developments in risk factors and treatment. Also covers the five diagnostic criteria that must be present to make an accurate diagnosis of ARDS, including clinical, radiographic, and physiologic criteria. **Item VT31**

Practical Management of ARDS

By David J. Pierson, MD. Adult respiratory distress syndrome is defined in this informative tape and its clinical features described, including incidence of risk factors and clinical predictors. Also extensively discussed is the use of PEEP to treat ARDS, including goals, complications, best or optimal PEEP levels, PEEP trials, and PEEP withdrawal, as well as general treatment, prognosis, and sequelae of ARDS. **Item VT16**

Tissue Oxygen Delivery

By David R. Dantzker, MD. Discusses the relationship between adequate tissue oxygenation and adequate energy production, the development of lactic acidosis, and the probable role of tissue hypoxia in the multiple-organ failure of ARDS. Also discusses the factors that govern oxygen transport to the tissues and the variables that reflect the adequacy of tissue oxygen transport. **Item VT26**

The Hospitalized COPD Patient: 10 Commandments For the Clinician

By David J. Pierson, MD. Takes you inside the decision-making process of caring for a respiratory care patient with chronic obstructive pulmonary disease. Details the ten rules for the clinician to follow when the COPD patient presents to the hospital. Emphasis is on the "what not to do." **Item VT29**

Pulmonary Rehabilitation

By John E. Hodgkin, MD. Provides an overview of the sequence for pulmonary rehabilitation. Learn candidate evaluation and selection, rehabilitation team establishment, identification of short- and long-term goals, program components, assessment of patients' progress, and long-term follow-up. Discusses aerosol therapy, IPPB, oxygen therapy, and chest physiotherapy in the treatment of COPD. **Item VT7**

Clinical Use of the Swan-Ganz Catheter

By John Marini, MD. Clinical applications of data obtained by Swan-Ganz catheter placement and the situations in which SGC placement are useful are described in this video. The clinical value of the clinical variables monitored by SGC and the complications of its placement are detailed, including "damping" of the waveform, "overwedging," and optimal lung zone placement. **Item VT22**

Drainage of the Pleural Space: Management of Chest Tubes and Bronchopleural Air Leak

By Martha L. Tyler, RN, RRT. Learn the physiologic effects of abnormal pleural space function and the potential problems associated with chest tubes stripping, difficulties of bronchopleural air leaks with mechanical ventilation, the therapeutic goals of chest tube placement, and techniques for maintaining gas exchange with air leaks. **Item VT21**

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For a limited time, you may also order the 1987, 1988, and 1989 bound volumes at the discount price of $30.00 for AARC members and $70.00 for nonmembers. The 1990 Bound Volume is now available for $35.00 for AARC members and $75.00 for nonmembers. *Orders must be prepaid, or include an institutional purchase order, or credit card.*

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B ❑ Cardiopulmonary
C ❑ Anesthesia Service
D ❑ Emergency Dept
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1 ❑ Clinical Practice
2 ❑ Pennatal Pediatrics
3 ❑ Critical Care
4 ❑ Clinical Research
5 ❑ Pulmonary Function Lab
6 ❑ Home Care/Rehab
7 ❑ Education
8 ❑ Management
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B ❑ Chief Therapist
C ❑ Supervisor
D ❑ Staff Technician
E ❑ Staff Therapist
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